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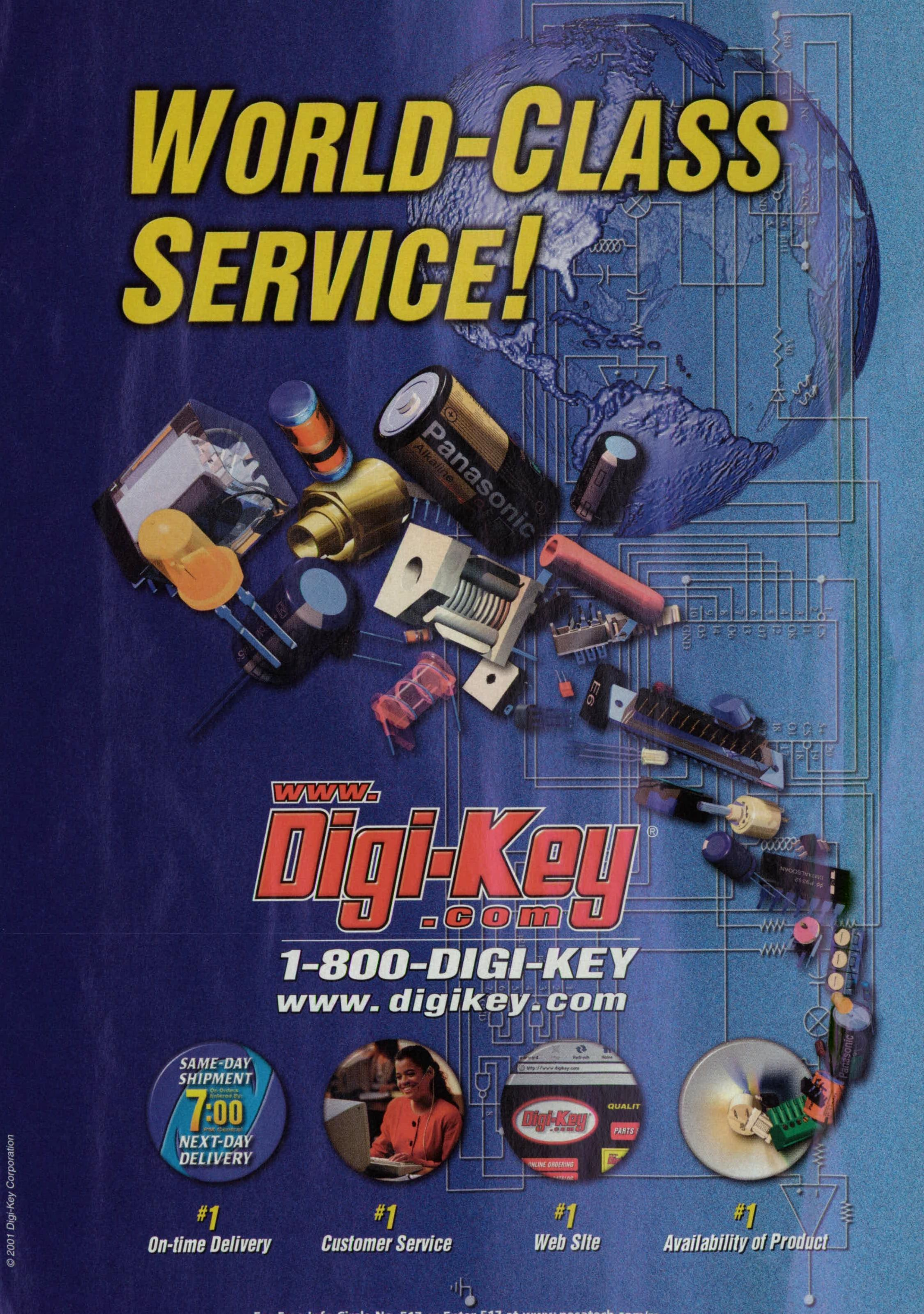
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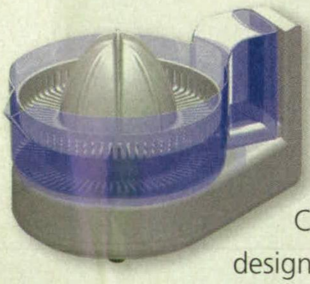

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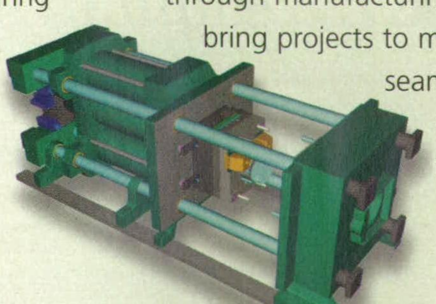

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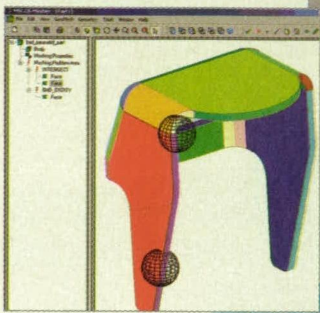
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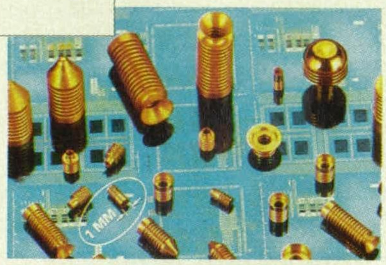
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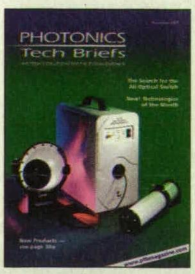

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PRODUCT OF THE MONTH

Measurement Studio™ 6.0 software from National Instruments (Austin, TX) lets engineers create a variety of integrated test, measurement, and control applications in the programming language of their choice.

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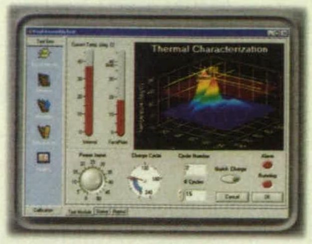

ON THE COVER

Mechanical Event Simulation technology from ALGOR, Inc., Pittsburgh, PA, was used to replicate the dynamic motion of this Peaucellier Cell and simultaneously calculate the stresses caused by the motion. The geometry for the assembly was seamlessly captured from Solid Edge through ALGOR's InCAD technology. Analysis software, in general, is becoming easier to use, thanks to an effort by vendors to make engineers and designers more productive. See the feature beginning on page 25 for more on the issues facing analysis software providers and users.

(Image courtesy of ALGOR, Inc.)


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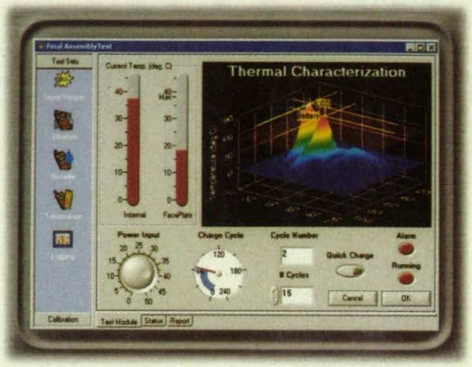
UpFront

PRODUCT OF THE MONTH

National Instruments, Austin, TX, has introduced Measurement Studio™ 6.0, a set of integrated measurement tools that engineers can use to create test, measurement, and control applications in various programming languages. The software supports LabWindows™/CVI, Microsoft Visual Basic, and Visual C++. Vision and motion hardware also can be integrated into measurement applications through task-oriented software. With the new version's visualization tools, engineers can display data on real-time 3D or 2D graphs and charts that can be annotated to explain significant dips or spikes in the data. The graphs and other data can be shared via DataSocket™, a publish/subscribe technology that provides simplified URL addressing. Real-time data can be viewed from a test that is occurring in another part of the world. Other features include signal analysis functions and interchangeable virtual instrumentation (IVI) class compatibility.



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Robotic Surgery Spans an Ocean

Recently, a 68-year-old woman in Strasbourg, France, became the first patient in history to receive a complete surgical operation performed by surgeons in New York — nearly 4,000 miles away.

Prof. Jacques Marescaux (l) and Dr. Michel Gagner are seated at the controls of the Zeus Robotic Surgical System in New York, performing surgery on a patient in France. (Photo courtesy of Computer Motion)

Dr. Michel Gagner, chief of laparoscopic surgery at New York's Mt. Sinai Hospital's School of Medicine, and Professor Jacques Marescaux of the European Institute of Telesurgery, removed the woman's gallbladder using the Zeus® Robotic Surgical System from Computer Motion of Santa Barbara, CA. Dr. Gagner manipulated the arms of his computer system in New York, and the instructions were transmitted via a high-speed fiber-optic service provided by France Telecom.

Dr. Gagner operated the laparoscope — a tubular surgical instrument — while receiving pictures from inside the patient's body. He and Professor Marescaux could work with a time delay of only 150 milliseconds, which means the messages guiding the surgical instruments had to travel from New York to France and back again in less than one-sixth of a second.

The technology also could be used to teach doctors who work in underdeveloped areas. "We can now extend the reach of the surgeon so that an expert can intervene any place in the world," said Marescaux. "I felt as comfortable operating on this patient as if I had been in the room."

For more information, visit ***www.computermotion.com.***

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Beginning with this issue of *NASA Tech Briefs*, you now have a choice of receiving a digital (pdf) version of the magazine in addition to or instead of your print copy. The pdf edition is a full-color replica of the printed magazine, with many added benefits, including the ability to search and archive digital issues, hyperlink directly from articles and ads to Web pages, and view embedded video and audio clips.

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Cast Your Vote

It's almost time to vote for the 2001 *NASA Tech Briefs* Readers' Choice Product of the Year Awards. Next month's issue will have the official rules and voting instructions you need to cast your vote for the most significant new product introduced to the engineering community this year.

NASA Patents

Over the past three decades, NASA has granted more than 1000 patent licenses in virtually every area of technology. The agency has a portfolio of 3000 patents and pending applications available now for license by businesses and individuals, including these recently patented inventions:

In Vivo Simulator for Microwave Treatment

(U.S. Patent No. 6,175,768)

Inventors: G. Dickey Arndt, James R. Carl, George W. Raffoul, Vincent G. Karasack, Antonio Pacifico, and Carl F. Pieper, Johnson Space Center

This invention provides methods and apparatus operable for thermally ablating arrhythmogenic cardiac tissue to treat ventricular tachycardia, or rapid pumping of the heart ventricles, while controlling the temperature rise in nearby blood and heart tissues. The system can raise the temperature of deeply situated arrhythmogenic cardiac tissue by a sufficient level (about 20 degrees C) for thermal ablation without boiling or vaporizing blood or charring or burning surface tissues. For this purpose, a catheter is provided with a microwave radiator at one end. A frequency of operation is selected, between about 1 and 12 GHz or higher, so that a temperature increase from absorption of microwave energy in the blood is limited by the blood exchange rate to a desired temperature range. The catheter is positioned to place the microwave radiator adjacent and preferably in contact with the arrhythmogenic tissue. The radiator will therefore typically be surrounded by blood. A microwave signal of a selected frequency is conducted through the catheter to the radiator for the desired heating time.

Polyimide Precursor Solid Residuum

(U.S. Patent No. 6,180,746)

Inventors: Erik S. Weiser, L. St. Clair, Yoshiaki Echigo, and Hisayasu Kaneshiro, Langley Research Center

Polyimide foam materials have a number of beneficial attributes for next-generation space vehicles, such as high temperature and solvent resistance, flame resistance, low smoke generation, high modulus and chemical and hot water resistance. Another area for polyimide foams is in the manufacture of low-density insulation for thermal and acoustic applications, and reinforcement for the maritime industry. The foamed products produced by current methods often exhibit nonuniformity of density and cell size throughout the foamed structure, which results in low yields of acceptable product. Additionally, some of the polyimide precursors employed in related art processes, especially those involving isocyanate chemistry, have poor hydrolitic stability and poor stability toward other types of decomposition. The inventors have provided a polyimide precursor solid residuum that has particular utility and special effectiveness in the preparation of polyimide foam and the fabrication of polyimide foam structures. The residuum is an admixture of an aromatic dianhydride or derivative thereof and an aromatic diamine or derivative thereof.

Refractory Oxidative-Resistant Ceramic Carbon Insulation

(U.S. Patent No. 6,225,248)

Inventors: Daniel B. Leiser, Ming-ta Hsu, and Timothy S. Chen, Ames Research Center

Low-density insulations are required to thermally protect the structure of the Space Shuttle from the high temperatures normally encountered during atmospheric entry. A characteristic of a successful insulation is high thermal shock resistance. The temperature limitations of current materials and the desirability of improving their mechanical properties are reasons for developing alternative materials. The invention relates to lightweight, high-temperature ceramic insulation, that is, a carbon tile combining carbon, silicon, and oxygen derived from the reaction of an organodialkoxy silane and an organotrialkoxy silane to form a sol-gel in the presence of a porous carbon substrate. This tile would be able to retain its shape and strength when exposed to an oxidizing environment at temperatures in excess of 1200 degrees Celsius. The method of this invention starts by coating or impregnating a porous carbon substrate with the reaction product to form a gel *in situ*, or in the presence of the porous carbon substrate, followed by drying the substrate and subsequently heating or pyrolizing it, in an inert atmosphere, to form the ceramic carbon insulation.

For more information on the inventions described here, contact the appropriate NASA Field Center's Commercial Technology Office. *See page 24 for a list of office contacts.*

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I am looking to purchase Nafion membrane N-117. Does anyone know where I can obtain this? Any information is greatly appreciated.

Ping Liu
pingliu2001@yahoo.com

*(**Editor's Note:** Ping, Nafion is a DuPont resin that is available in membrane form. The non-reinforced films, or membranes, are based on Nafion, which is a perfluorosulfonic acid/PTFE copolymer in the acid form. Visit the DuPont Web site at: www.dupont.com, or contact the Nafion Tech Service center at 800-436-1336.)*

Where can I find information on the benefits that have been realized from advances in space technology, and the conveniences that they have provided?

tapley@accucomm.net

*(**Editor's Note:** Many Americans are unaware of the technologies and products we use every day that trace their origins to the space program and to NASA development. NASA produces an annual publication called* Spinoff *that features stories on the successful transfer and application of NASA-generated technology, and how that technology is applied to new commercial products. Go to **www.nasatech.com/spinoff**, and you can view and download current and recent issues of* Spinoff.*)*

There was a tech brief in a past issue of *NASA Tech Briefs* that described Delta-Doped Hybrid Advanced Detectors (October 1998). I would like to evaluate these detectors for a charged particle instrument application. I'd like to know if these devices have been successfully produced, and if the units are available for evaluation.

Walter Lockhart
wlockhart@coolohms.com

*(**Editor's Note:** Walter, the work was performed by a team from Caltech for NASA's Jet Propulsion Laboratory (JPL) in Pasadena, CA. You can get further information on the invention and its licensing from the Intellectual Property group at JPL; Tel: 818-354-2240. Refer to the tech brief number NPO-20111 and the issue in which it appeared.)*

Technologies of the Month

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For more information on these and other new, licensable inventions, visit www.nasatech.com/techsearch

Quick Chilling Technology Holds Promise for Diverse Uses

Carol Kralicek, Enersyst

Based on convection currents, a new chilling and thawing technology chills food up to 15 times faster and thaws foods up to three times faster than conventional chilling technologies. Using jets of air directed at the surface of the item to be cooled, it rapidly and evenly changes the temperature of the food by disturbing the layer of stagnant air next to the surface. Called "air impingent cooling," this technology directs or "impinges" jets of air perpendicularly against a product's surface at a rate of several thousand feet per minute. This action creates high- and low-pressure areas that assist in the movement of the air, accelerating the cooling.

This technology can be retrofitted to existing refrigeration units or can operate as a standalone cooling system, chilling and thawing food and beverages as needed. Applications include the food manufacturing and service industries, as well as metallurgy, HVAC, and laboratory processes that require rapid cooling.

Get the complete report on this technology at:
www.nasatech.com/techsearch/tow/enersyst.html

A Unique Way to Produce Ultra Low Sulfur Diesel (ULSD)

Dr. W.S. Min, SK Corporation, Taejon R&D Center

Many governments have restricted the amounts of contaminants, sulfur, NOX, particulates, and/or aromatics and olefins a petroleum-based fuel may have in order to assure a cleaner atmosphere when these fuels are burned for energy. Hydro-desulfurization, a hydrogen treating process, has been the prime method of contaminant removal, but it requires high levels of pressure and temperature. And nitrogen compounds in the diesel feedstock inhibit the catalytic reactions needed to remove contaminants.

The new technique is an adsorption type process that removes about 90% of undesirable nitrogen compounds from the diesel feedstock that would normally go directly to a hydro-desulfurization unit for sulfur removal. The absorbers are liquid-filled at all times, and can last for at least one year. Common solvents are used, and the final diesel product has lower amounts of sulfur, a lighter color, and better storage stability.

Get the complete report on this technology at:
www.nasatech.com/techsearch/tow/sk.html

Rotating Device Performs as Seal, Bearing, or Pump

Douglas T. Bridge, Principal Engineer, Advanced Technology Development, A.W. Chesterton

This new rotating device is based on Taper Spiral Groove (TSG) technology, a tapered, grooved rotor that uses spiral grooves to create a concentric film between the stator and the rotor that can be adjusted for thickness and flow. When used as a bearing, the device replaces bulky, radial and axial bearings with their larger housings and support systems. As a pump, the device provides high-pressure, low-flow performance that can be used to hydraulically load other devices, such as lubricating systems. As a wind-back seal or visco seal, it prevents liquids from leaking along rotating shafts.

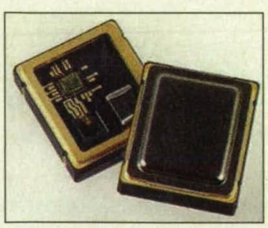
TSG technology reduces equipment vibration and wear, and can be used for pumps, gear boxes, turbines, compressors, and other rotating equipment in process industries such as pulp and paper, pharmaceuticals, and chemical manufacture. It also has applications in utilities, transportation and heavy equipment, marine systems, and agriculture.

Get the complete report on this technology at:
www.nasatech.com/techsearch/tow/chesterton.html

New Sensors Adaptable to a Range of Applications

Toshihide Kuriyama, NEC

Two new sensors are showing potential for transportation and communication applications. The first is a semiconductor-based acceleration sensor that uses silicon etching methods to create a smaller base in the middle of the chip, thus increasing stability. They are ideal for detecting vehicle speed to assist safety and suspension systems. Acceleration data from the sensors can be used to determine velocity and position for guidance, navigation, and positioning applications in industries such as avionics, automotive, robotics, GPS, defense, and civil engineering.



The second sensor can replace the PC mouse with a stationary device that features two finger sockets that contain a series of capacitance sensors to track finger movement within the socket space. These sensors enable precise positioning of a cursor on a computer screen making it ideal for applications requiring cursor-based interactivity, such as virtual reality, navigation systems, personal digital assistants, and computer-aided design and manufacturing systems.

Get the complete report on this technology at:
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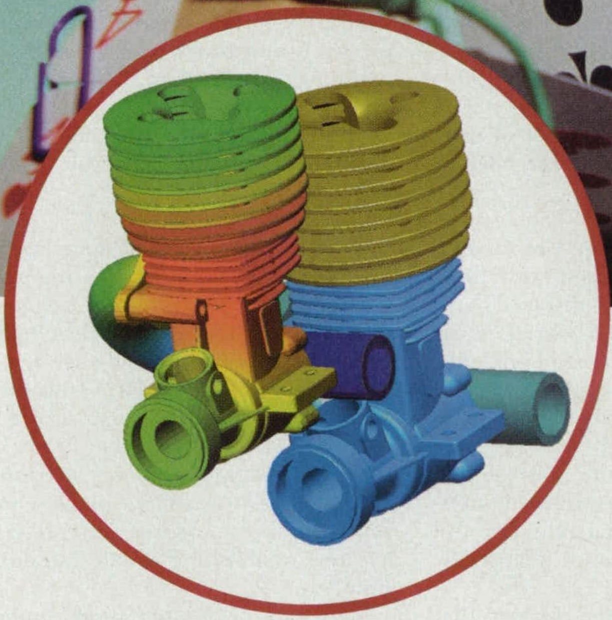

Who's Who at NASA

Dr. Yoseph Bar-Cohen, Senior Research Scientist, Nondestructive Evaluation (NDE) Group, Jet Propulsion Laboratory

Dr. Bar-Cohen is a physicist specializing in ultrasonic NDE and electroactive materials and mechanisms at NASA's Jet Propulsion Laboratory in Pasadena, CA. He established the Nondestructive Evaluation and Advance Actuators (NDEAA) Lab in 1991. Currently, he is developing electroactive polymer actuators — artificial muscles — and an ultrasonic drill.

***NASA Tech Briefs:* What types of technologies are developed at the NDEAA Lab?**

Dr. Yoseph Bar-Cohen: The focus is on phenomena associated with time-dependent mechanical displacements in the form of waves or vibrations induced by electroactive materials. We are seeking planetary applications and potential spinoffs to aerospace, medical, and commercial areas. Currently, we are developing the Ultrasonic/Sonic Drill/Corer, electroactive polymers (EAP) as artificial muscles, and medical treatment and diagnostic methods.

Some of the unique devices that we've developed include a dust wiper and a gripper that excited the imagination of many with regards to the potential of EAP materials. In the high-frequency and high-power domain, we are exploring medical treatment methodologies jointly with the UCLA Medical Center.

NTB: Have any of these innovations been spun-off by NASA for commercial use?

Dr. Bar-Cohen: We are continually seeking avenues to commercialize our technologies, both through our own initiatives and in response to inquiries. The ultrasonic drill, which we are developing jointly with Cybersonics, is already being produced commercially by our partner. This drill is capable of drilling with low power and low pressure on the bit, drilling rocks as hard as basalt and granite. It does not require sharpening and it extracts the produced powder via an ultrasonic transport mechanism up the drilling bit. We also developed an ultrasonic rock abrasion tool (URAT) as a backup device to the Mars 2003 mission. We also have other technologies with great potential, including our piezopump that potentially can be used as a beeper-sized peristaltic system to inject multiple types and doses of medications in real time.

NTB: You're also working on the MEMICA program. Can you tell us about that?

Dr. Bar-Cohen: It is a haptic system of remote MEchanical MIrroring using Controlled stiffness and Actuators (MEMICA) that we are developing jointly with Prof. Mavroidis from Rutgers University. MEMICA was conceived to provide teleoperators with an intuitive feel of objects that are being remotely manipulated. It will potentially augment astronaut activity, providing countermeasures for zero-gravity, and establishing medical training simulators.

MEMICA offers potential applications both as a telepresence system using a surrogate robot, or virtual reality. This technology is expected to have many spinoffs, including medical, military, sports, training, and entertainment. For space, we are envisioning applications such as remote operation of robots, where it could maneuver through areas too small for the current Space Station robots. It also can be used for simulated medical procedures, providing the capability to train or remotely guide a medical staff. With the aid of all-in-one type surgical tools, astronauts with medical backgrounds would be able to perform urgent care procedures as they develop.

*A full transcript of this interview appears on-line at **www.nasatech.com/whoswho**. Dr. Bar-Cohen can be reached at yosi@jpl.nasa.gov.*


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NASA's Technology Sources

If you need further information about new technologies presented in *NASA Tech Briefs*, request the Technical Support Package (TSP) indicated at the end of the brief. If a TSP is not available, the Commercial Technology Office at the NASA field center that sponsored the research can provide you with additional information and, if applicable, refer you to the innovator(s). These centers are the source of all NASA-developed technology.

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Dryden Flight Research Center
Selected technological strengths: Aerodynamics; Aeronautics Flight Testing; Aeropropulsion; Flight Systems; Thermal Testing; Integrated Systems Test and Validation.
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Goddard Space Flight Center
Selected technological strengths: Earth and Planetary Science Missions; LIDAR; Cryogenic Systems; Tracking; Telemetry; Remote Sensing; Command.
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Jet Propulsion Laboratory
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Johnson Space Center
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Kennedy Space Center
Selected technological strengths: Fluids and Fluid Systems; Materials Evaluation; Process Engineering; Command, Control and Monitor Systems; Range Systems; Environmental Engineering and Management.
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NASA ON-LINE: Go to NASA's Commercial Technology Network (CTN) on the World Wide Web at **http://nctn.hq.nasa.gov** to search NASA technology resources, find commercialization opportunities, and learn about NASA's national network of programs, organizations, and services dedicated to technology transfer and commercialization.

NASA Program Offices

At NASA Headquarters there are seven major program offices that develop and oversee technology projects of potential interest to industry. The street address for these strategic business units is: NASA Headquarters, 300 E St. SW, Washington, DC 20546.

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Mississippi Enterprise for Technology
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Julie Holland
NASA Commercialization Center
Pomona, CA
(909) 869-4477

Bridgette Smalley
UH-NASA Technology Commercialization Incubator
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(713) 743-9155

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Hampton Roads Technology Incubator (Langley Research Center)
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If you are interested in information, applications, and services relating to satellite and aerial data for Earth resources, contact: Dr. Stan Morain, **Earth Analysis Center,** (505) 277-3622.

Ease of Use is Key for Analysis Software Vendors

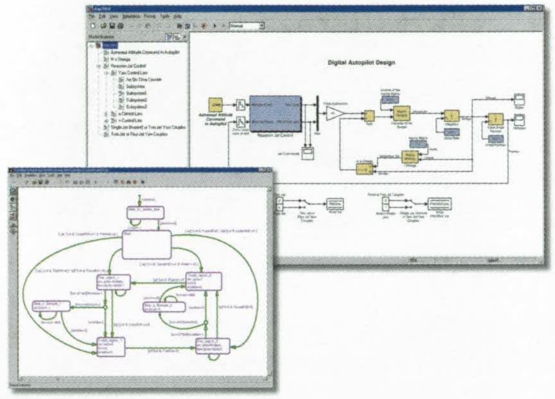
Making the design process better — that's the focus of both CAD and analysis software tools. Increasingly, these two areas of engineering software are moving closer together to provide users with what they've been demanding — the ability to work the way they want to.

Analysis and simulation tools are introduced into the product development process when the first conceptual design and engineering work begins, according to Jim Tung, chief market development officer for The MathWorks, which provides MATLAB and Simulink analysis tools. "Whatever is being created — whether it's a cell phone, an airplane, or a car — at the end of the day, it's going to be a multi-domain, multi-disciplinary problem" requiring both CAD and analysis. Preserving this hand-in-hand relationship means that the CAD and analysis products must take advantage of each other's capabilities. "CAD packages have become more widely used in the design process, so there are many benefits if an analytical tool can leverage the modeling power within those CAD packages," said Bob Williams, product manager for ALGOR, Inc., a provider of finite element analysis (FEA) tools.

CAD is often thought of as the design tool, and analysis as the verification tool. "In the physical world, you build something and test it," said Ken Blakely, vice president of MSC Software, a provider of analysis and simulation software. "If it doesn't work, you re-do it. Today, you design something in CAD and you do the design verification using analysis."

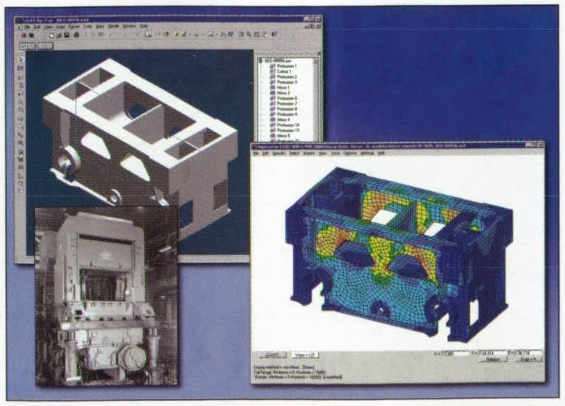
Analysis and simulation packages also are becoming easier to use, making the distinction between a CAD operator or designer and an engineer or analyst much more blurred. "We work with SolidWorks, Solid Edge, Mechanical Desktop, Inventor, CADKEY, and Pro/ENGINEER," said Williams. "There are certain ways of operating within each of these modeling programs. Analysis software providers must offer tools that allow users from each of these different CAD and engineering backgrounds to be able to efficiently leverage analytical tools."

Various levels of education and training come into play when discussing ease of use. Analysis and simulation software has long been considered the domain of engineers. That is changing. Suchit Jain, vice president of marketing for Structural Research & Analysis Corp. (SRAC), maker of the COSMOS line of analysis products, believes that analysis software is definitely becoming easier to use. "Sixty to 70 percent of the time when you're designing in CAD and you need to check performance, you're looking for a very limited functionality within an FEA product. The need most of the time is for a very specific scenario. It's like when you buy a TV. You think, 'I may not use all 100 channels,' but it's good to have them."



Simulink and Stateflow from The MathWorks provide model-based design, analysis, and simulation capabilities, with interfaces to domain-specific modeling and CAD packages.

A significant learning curve still exists for mastering analysis software, but Tung believes that may be misleading. "CAD programs are easy to get into, but it takes a long time to become a master user." The difference, he explained, is ease of introduction. "A CAD tool has a learning curve that's very gradual, but it goes up rather steeply. Analysis tools have a curve that's steeper at the beginning, but it will drop off. Once you've mastered the fundamentals of analysis tools, it's easier to do a lot of different things."



Danly Engineering Services, a division of Enprotech Mechanical Services, analyzed a modification to a power press located at a General Motors plant to accommodate a different die. Engineers built the modified geometry in Solid Edge and used ALGOR's fully associative InCAD technology to capture the model and perform a finite element analysis.

Does Collaborative Analysis Exist?

CAD vendors have taken advantage of the Internet in a big way, incorporating

collaborative capabilities that enable users to share and interact with each other's models and related data. While the need for collaboration exists in the analysis and simulation area, many view analysis software as a more individually oriented product.

Research Systems is an Eastman Kodak company that produces IDL® data analysis and visualization software that is used by customers such as NASA for image analysis. Richard Cooke, vice president of engineering for Research Systems, explained that his company spends a significant amount of time looking at architecture in terms of how it plays into the Internet world. "Collaboration is one key. NASA, for example, doesn't just want to serve up image data," said Cooke. "They want certain pieces of our analysis tools available to the person looking at the image on the Internet, so he or she can manipulate the image. Everything we do in the scientific and engineering world eventually will need to be shared and collaborated on over the Internet."

This 3D visualization of charge density is displayed in IDL software from Research Systems. The data was provided by Lloyd Treinish of Lawrence Livermore National Lab.

The Internet hasn't taken off as a collaboration tool for analysis software users for a number of reasons, said SRAC's Jain. "For high-end FEA products, the software takes a long time to run, and FEA usually produces a lot of data that may be proprietary." Jain does see an even broader use, however. "We know that using the Internet as a computing platform is something that will be present in the future. People will start using Microsoft. NET as a popular platform," Jain predicted.

MSC's Blakely believes that the Internet has not had a huge impact on the analysis software market yet, but that a change is coming. "What I do expect to see over the next few years is people using the Internet to pull together models that have been analyzed in different places." MSC and other vendors continue to expand their use of the Internet more as a communications and training tool than an interactive collaboration tool.

"The Internet has allowed a wider use of technology to help end users of products learn how to use those products, stay up to date on what's available for that product, and continue to leverage new capabilities," said ALGOR's Williams. "As a piece of the whole puzzle, there definitely is a need for collaboration within analysis," he explained. "It won't be as interactive a collaboration, but you can keep data coupled together so if someone makes a change, the others will know about it. After running an analysis, reporting and presentation tools allow you to publish the results to a Web site so others can benefit from the knowledge gained from the analysis."

Computing Power and Other Trends

Software vendors are taking a closer look at their users' computing power and platforms to plan for future demands. According to Tung, The MathWorks sees a trend towards the number of users doing analysis work on Windows-based machines. "I don't think UNIX will go away," Tung said. "Devel-

opment and design teams will have to be multi-environment. An individual user may work only on Windows or UNIX, but they need to share their ideas across platforms."

As PC computing power increases, there will be less of a comparison between how analysis is run on UNIX and PCs. What ALGOR is focusing on, according to Williams, is the PC chip. "Many of them are beginning to have special instruction sets to allow math operations to occur more quickly. We also are looking at the ability to leverage multiple processors on the PC," Williams said.

Most vendors agree that there is — and must continue to be — an even more important trend in the analysis software arena: ease of use. Computing power, collaborative capabilities, and close communication with the CAD vendors are all important, but the bottom line is making the software easier to use, improving engineers' productivity.

Cooke recognizes that Research Systems, like other vendors, needs to focus more on ease of use. "IDL is a very robust analysis tool, but it does require some level of programming skill. We believe we'll have to broaden the market by extracting that programming layer even more."

Whether it's a designer or an engineer who's operating the software, productivity needs to be the main concern. The engineers and designers who perform the analysis have to spend much of their time obtaining the right inputs and verifying them, said MSC's Blakely. "They spend more time on that than doing the analysis itself. Engineers, in many cases, have become expensive bookkeepers," he added. "We need to change that and free up more of the engineers' time, so they can become innovators and truly add value to a company's product."

The best way to ensure that productivity is to let engineers work the way they want to work, according to ALGOR's Williams. "We want engineers to be able to model parts in CAD packages, analyze those parts in packages that have the robust capabilities to perform those analyses, and have them all work together very well."

*Visit **www.nasatech.com/features** for more comments from industry leaders on the analysis software market.*

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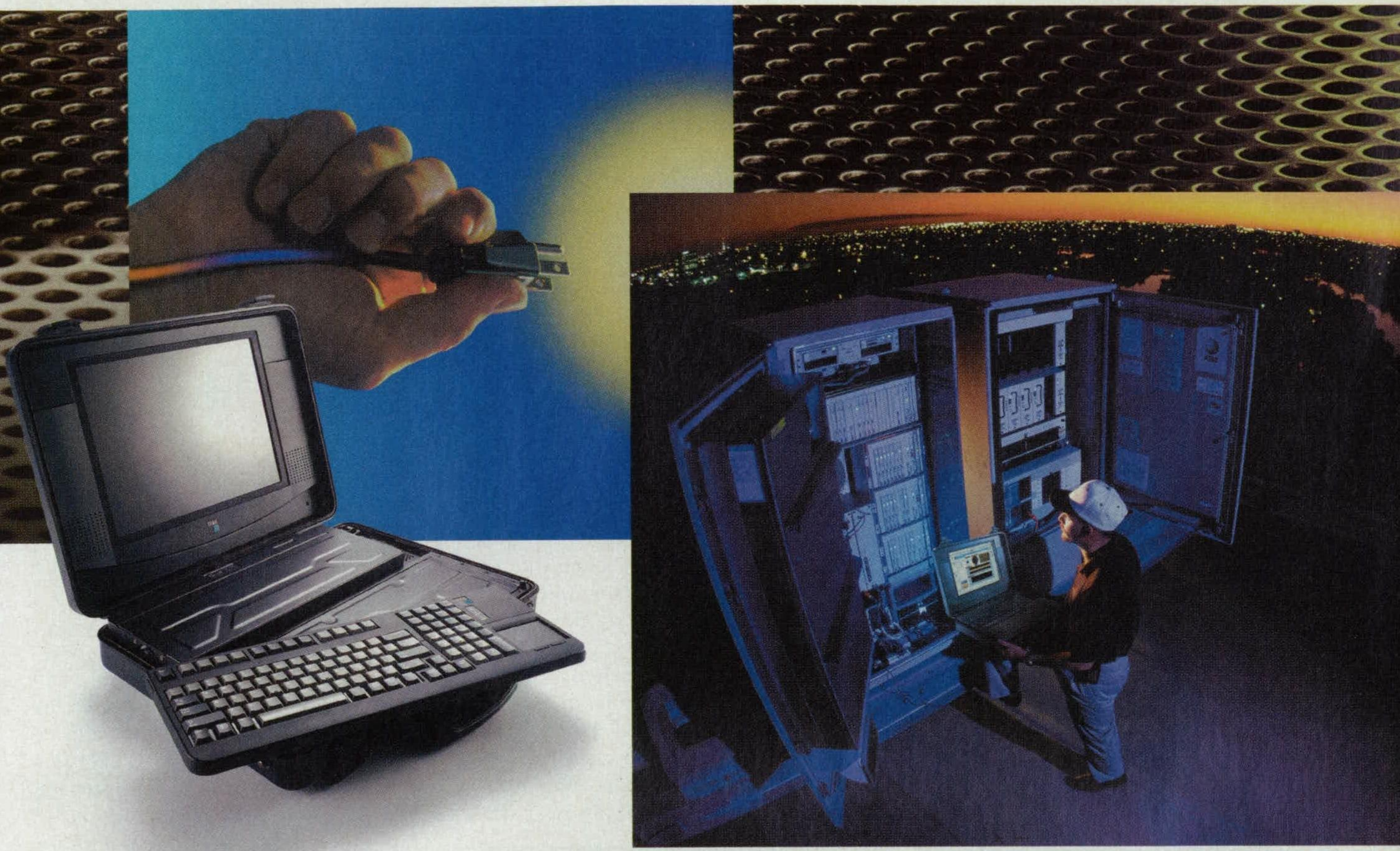

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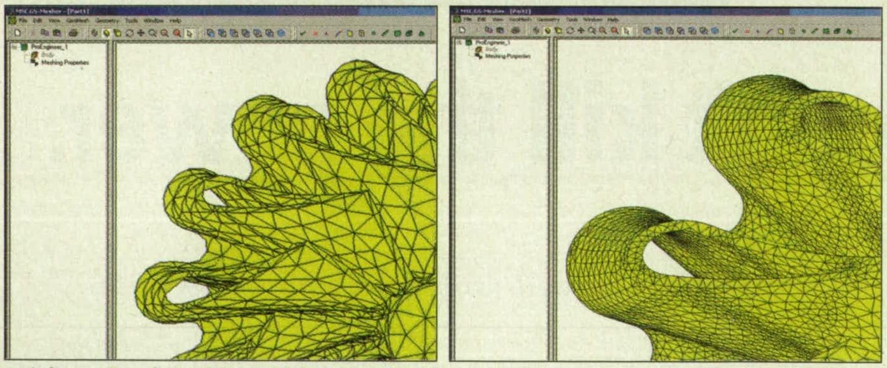
MSC's "Clean" Meshing Solution

Steven S. Ross

If you routinely try to run finite element analysis (FEA) on very large models (1,000 faces or more), you know one of the biggest bottlenecks — minor defects in the CAD file of the model itself can make mesh generation impossible. You go back and forth between the meshing engine and the CAD software, trying to get all your model elements aligned correctly. Also, translating from the model into something the meshing engine understands can mean lost detail.

MSC Software has come up with a nifty solution — a solid and surface meshing engine called GS-Mesher 1.1 that works directly on CAD files with no translation step, so that the files can be cleaned quickly and meshes modified without having to go back to the CAD package itself. Right now, it works with UGS Parasolid models (it handles them directly) and Pro/Engineer (it runs Pro/E in the background to do the CAD cleanup). CATIA V4 capability is promised soon. If demand warrants, MSC says there's no reason why versions for such CAD systems as SDRC I-DEAS, and packages using the ACIS solid modeling kernel, IGES, and VDA can't be offered. It runs in Windows NT or Windows 2000. I reviewed on a new Win2000 machine with 1.6 GHz processor and 512 MB of RAM. Meshes calculated almost instantaneously.



At left are tips of a turbine modeled with the default 45 degree curvature control. At right are the tips modeled after setting curvature to 15 degrees.

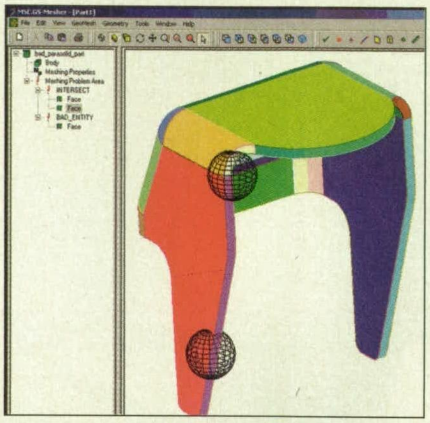
When any vendor brags about fixes in CAD models being automatic, or almost automatic, I tend to get very skeptical. From a quality control standpoint, any software that makes it easier for less experienced personnel to do really complicated tasks requires a two-step reviewing process. First, I check whether the software works. Then, I check whether the software, even if it works, might get a sloppy user into trouble.

On review point one, the answer is clear: GS-Mesher works. I could not entirely perform the second check for this review, but I lean toward applause for no other reason than GS-Mesher avoids a translation step from the CAD file to something the mesh generator understands. For the review, I created a little seven-component machine using Autodesk Inventor, then imported the file into Pro/E. I imported it three times — once as perfectly as possible, and twice after creating two different misaligned faces between elements of a complex pawl. When I ran GS-Mesher on the part, it gave essentially the same mesh all three times. But that might have been due to the import process (Inventor and Parasolid are good at cleaning up those little mistakes all by themselves). When I ran Mesher with the part detached from its little machine and redone from scratch in Pro/E, GS-Mesher quickly highlighted the flaw and allowed me to easily fix it.

Here's how it works once you have your CAD model. You simply start GS-Mesher, open a blank file, and bring your CAD file in. The model then is examined inside GS-Mesher. The model's faces are automatically assigned different colors for ease of visualization. Create a mesh and change the settings or accept the defaults.

Once the mesh is calculated, you can make it finer in a selected area, and specify a smaller mesh over this face. Click on an icon to draw the whole mesh, and export the mesh.

There are two export options — as an MSC.Nastran bulk data file or as an MSC.Patran database. I confirmed the calculations on our simple part (40 faces) by stressing the meshes inside MSC.Nastran, with no further processing. The examples in the figures show how the curvature control works to produce a finer mesh around sharp curves. GS-Mesher outputs solid 3D tetrahedral, surface paved, and 2D triangular meshing.



Model part with failed mesh (marked with spheres). Failure reasons are noted on the left.

If the mesh fails, the failure points are marked with spheres and an error message appears. The nature of the problems that caused the failures are "called out" in the window at the left of the screen. Clicking on the listings allows you access to each failed point in turn, so that you can specify a fix. You can hide all the faces except those that are causing problems — a boon when the model is as complex as an engine block. GS-Mesher tells the CAD software, running in the background, to fix the problem — intersecting face, bad entity, and so forth.

The copy protection is state-of-the-art. Along with other MSC products, it uses the FlexLM licensing database system. For more information, as well as pricing details, contact MSC Software at 714-540-8900, or visit www.mscsoftware.com.

Steve Ross is a visiting professor at Boston University this year, where he co-directs the new Institute for Analytic Journalism.

Special Coverage: Data Acquisition

Saturation Technique for Rapid Binary Image Processing

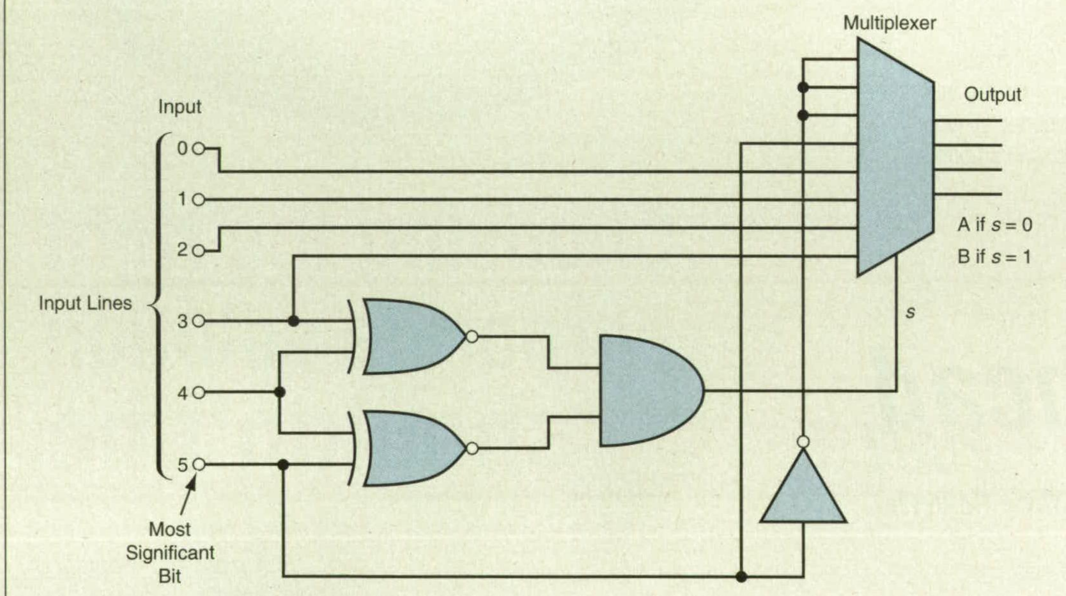
This technique is fundamentally different from truncation of least-significant bits.

Lyndon B. Johnson Space Center, Houston, Texas

An improved technique of limited-precision arithmetic has been devised for use in convolutional filtering of image data prior to conversion of the data to binary form. Both limited-precision arithmetic and conversion to binary form reduce the volume of data, thereby contributing to processing speed and reducing the sizes of circuits needed to perform, and store the results of, intermediate stages of processing. Applications in which these techniques are or could be helpful include robotic vision, recognizing and tracking moving targets, stabilizing images in hand-held video cameras, and general enhancement of images.

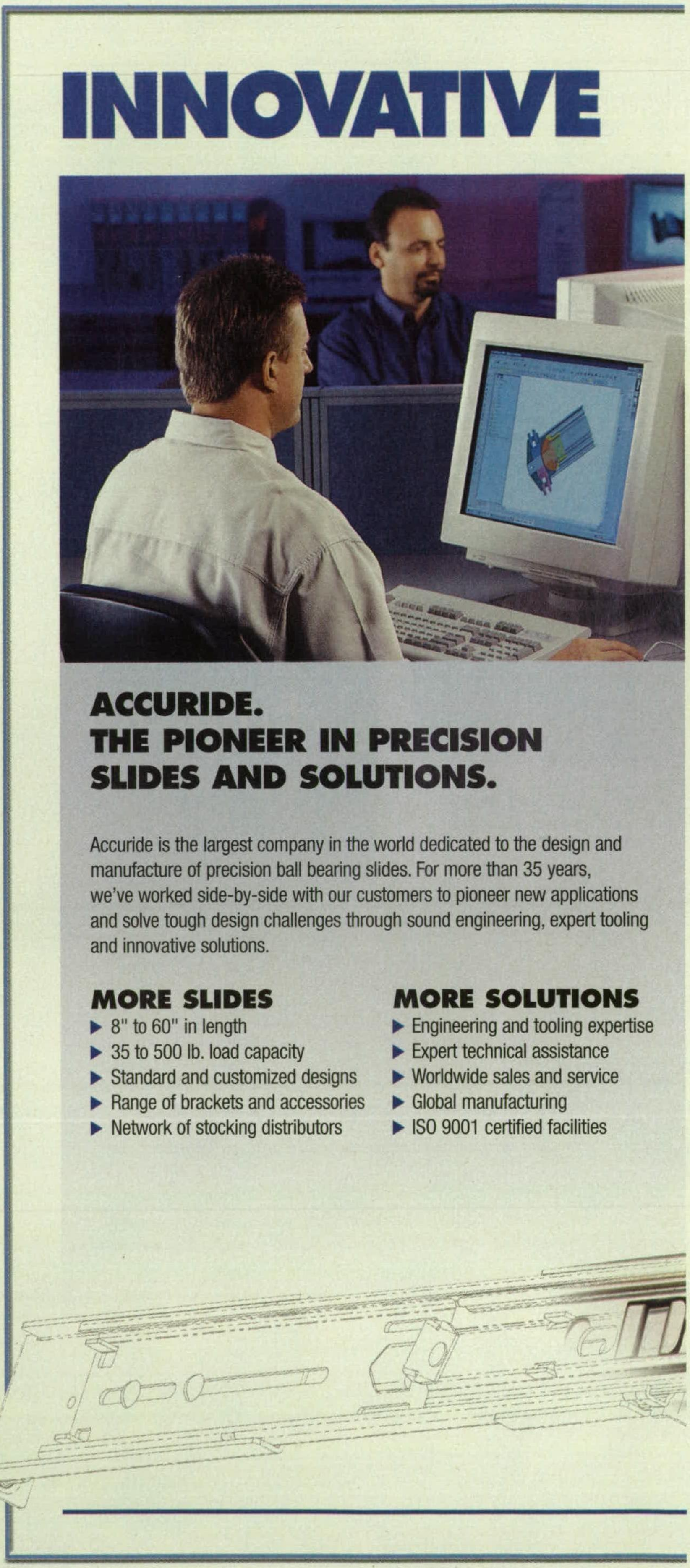
The improved technique of limited-precision arithmetic involves the use of saturation — the substitution of a specified datum for a datum of greater magnitude; this is fundamentally different from the conventional practice of truncation or rounding-off of least-significant bits. This technique was conceived especially for use in processing digitized pixel image intensities by convolutional 3 × 3 (or by equivalent combinations of 1 × 3 and 3 × 1 filters) that perform Gaussian, Laplacian, or Laplacian-of-Gaussian (LoG) operations on pixels in 3 × 3 neighborhoods. (Most LoG operations for neighborhoods larger than 3 × 3 can be composed of series of 3 × 3 operations: for example, the LoG for a 9 × 9 neighborhood can be computed by performing four successive 3 × 3 LoG operations.) These filters are typically applied to improve the reliability and consistency of mapping of pixel intensities to binary representation. A Laplacian filter emphasizes edges and texture, while a Gaussian filter smooths out noise.

The preferability of the present saturation-based technique over the conventional truncation-based technique arises in the treatment of intermediate results of Laplacian and Gaussian convolutional filtering of an image. Truncation or rounding sacrifices bits of low order to preserve the fundamental magnitude of a number as represented by the bits of high order. In the final conversion to binary, the bits of lowest order account for the finest detail in the resultant image. For a pixel value near zero, a change of +1 or −1 in a bit of low order can make a difference in the sign of the binary pixel value, possibly yielding the incorrect binary value (corresponding to a pixel that should be black instead of white or vice versa).



This Circuit Generates a Saturated Four-Bit Output in response to a six-bit input. The exclusive-OR gates examine the number of high-order bits to be eliminated, plus one, to determine whether they are already all alike. If so, the input quantity is deemed to be within the saturation range, and is itself gated through the multiplexer. If not, a maximum positive or negative quantity is derived from the sign bit and gated through the multiplexer. This circuit implements 2's-complement encoding of negative numbers.

In the present saturation-based technique, one discards high-order bits in such a way as to preserve correct sign of the pixel value in the final conversion to binary. In this technique, each pixel value is examined and modified as follows: If the value is larger than the largest value that can be represented in the result, then the pixel value is replaced by that largest value. Conversely, if the pixel value is negative or smaller than the smallest value that can be represented in the result, then the pixel value is replaced by that smallest value. The fig-



ure depicts a circuit that efficiently saturates a six-bit input to a four-bit output.

This work was done by Robert L. Shuler, Jr., of **Johnson Space Center**. *For further information, access the Technical Support Package (TSP)* ***free on-line at www.nasatech.com*** *under the Mechanics category.*
MSC-22850

Network for Forecasting Weather and Diffusion of Toxins

This system supplants a slower, less effective system.

John F. Kennedy Space Center, Florida

The Meteorological Range Safety Support System/Eastern Range Dispersion Assessment System (MARSS/ERDAS) is a system of interconnected computer workstations designed to acquire, process, and disseminate nearly real-time meteorological data and outputs of mathematical models of the atmospheric diffusion of toxic and otherwise hazardous substances. The MARSS/ERDAS hardware and software were developed to increase the effectiveness of NASA and Air Force range safety personnel. The basic MARSS/ERDAS concept could be adapted to industrial, agricultural, and scientific applications in which there are requirements to forecast weather to protect weather-sensitive assets and/or predict the movements of toxic plumes.

Prior to the development of the MARSS/ERDAS, the forecasting and mathematical modeling functions in question were performed, variously, by use of manual techniques or by use of central processors with asynchronous communications to remote sites. The manual processes required additional personnel for a number of tasks that were highly repetitive and the results of manual processing often included errors. The prior computer system was easily overloaded by user activities, and display updates were slow, because of both the load on the system and a slow communication link. Users were often disconnected and had to wait several minutes for reconnection.

The MARSS/ERDAS features a reliable, expandable, and flexible hardware and software architecture. The

software incorporates a program that implements a mesoscale meteorological model integrated with a program that implements toxic-diffusion-prediction algorithms. More specifically, the software incorporates the following programs: Regional Atmospheric Modeling System (RAMS), Isentropic Analysis (ISAN), Hybrid Particle and Concentration Transport (HYPACT). The system also enables local execution of the REEDM and BLASTX programs. Data displays can include graphics, text, and map overlays. The system can also be made to perform an expert-system meteorological-monitoring function that includes the generation of audible and visible alerts when specified meteorological constraints are violated.

This work was done by John Warburton, Greg E. Taylor, Allan V. Dianic, and Erik Magnuson of ENSCO, Inc., for **Kennedy Space Center**.

In accordance with Public Law 96-517, the contractor has elected to retain title to this invention. Inquiries concerning rights for its commercial use should be addressed to

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ENSCO, Inc.
1980 No. Atlantic Ave.
Suite 230
Cocoa Beach, FL 32931
Tel No: (321) 783-9735
E-mail: dianic.allan@ensco.com

Refer to KSC-12178, volume and number of this NASA Tech Briefs *issue, and the page number.*

Software for Processing Serial Cross Sections Into 3D Images

Ames Research Center, Moffett Field, California

The Reconstruction of Serial Sections (ROSS) computer program processes data from a series of tomograms to generate a three-dimensional (3D) representation of an object, and further processes data from the 3D representation to enable the viewing of any part of the object from any of an essentially unlimited number of perspectives. ROSS is expected to be especially useful for biomedical applications, including medical research, medical training, virtual-environment simulations for planning surgery, and

telemedicine. The main contributions of ROSS to the art of computational 3D imaging are ease of use, high fidelity, and general applicability. Even high-school students have been trained to use ROSS. The fidelity of the images generated by ROSS from tomographic data is great enough that surgeons can notice tiny defects in hearts and lungs, for example. Although a typical set of tomographic data is so large that, heretofore, it has not been possible to generate high-fidelity 3D views by use of a personal computer, ROSS makes it possible by rendering different components of images at different levels of resolution so that one does not lose sight of essential features and yet the overall amount of information to be processed is reduced drastically.

This program was written by Muriel Ross, Kevin Montgomery, Samuel Linton, and Rei Chang of **Ames Research Center.** *For further information, access the Technical Support Package (TSP)* ***free on-line at www.nasatech.com*** *under the Software category.*
ARC-14035

Software for Displaying and Comparing Wind-Tunnel Data

Ames Research Center, Moffett Field, California

DARWIN is a computer program that provides access, via the Internet, to geographically dispersed NASA computer archives of both meta-data and raw test data from wind tunnels and raw simulation data from computational fluid dynamics (CFD) sites. DARWIN facilitates the manipulation and examination of the raw data by presenting the data in two- and three-dimensional plots, and other visual displays. DARWIN provides a "live" window that can be used during a wind-tunnel test to generate a customized display of newly acquired data in nearly real time. By use of DARWIN, it is possible to display simultaneously, and hence compare, data from different tests or CFD simulations — even from tests performed at different sites or simulations performed on different computers. DARWIN is characterized by a three-tier (server/server/client) architecture: In a wind tunnel or at a CFD site, there is a secure server computer that houses the meta-data and the raw test data. The secure server transmits data files (only) to a central DARWIN server, which interacts with users and processes data according to users' requests while preserving the security of the archives.

This program was written by David Korsmeyer, Joan Walton, John Schreiner, and Dennis Kroga of **Ames Research Center.** *For further information, access the Technical Support Package (TSP)* ***free on-line at www.nasatech.com*** *under the Software category.*
ARC-14376

Integrated Environmental Monitoring Instrument

This is a semiautonomous reference instrument with radio-communication and networking capability.

NASA's Jet Propulsion Laboratory, Pasadena, California

A miniature, battery-powered, semiautonomous environmental monitoring instrument contains advanced meteorological sensors, a Global Positioning System (GPS) receiver for determining its position, radio-communication circuitry, and a controller that performs measurement, control, and data-communication interface functions. The instrument could serve as a high-accuracy radiosonde, though its intended use is in providing reference measurements for calibration and comparison of ordinary radiosondes.

The primary functions of the instrument are to periodically measure humidity, pressure, temperature, and position, and to report the measurements to a base station. The base station records the data stream as received, displays key parameters on a screen to enable monitoring of status, and pro-

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vides an uplink (radio-communication) interface for sending commands and operational parameters needed for instrument functions.

The meteorological sensors in the instrument are a commercially available micromachined pressure sensor, three commercially available fast-response thermistors, and a surface-acoustic-wave (SAW) hygrometer.

The SAW hygrometer was developed at NASA's Jet Propulsion Laboratory and was described in "Fast, High-Sensitivity Dew-Point/Frost-Point Hygrometer" (NPO-20006), *NASA Tech Briefs*, Vol. 21, No. 5 (May 1997), page 10a. A surface-acoustic-wave (SAW) device serves as the resonant frequency-selecting element of a radio-frequency (RF) oscillator. The frequency of oscillation is sensitive to condensation on the surface of the SAW device. The SAW device is mounted on a thermoelectric cooler, which is used to effect feedback control of the temperature of the SAW device to maintain equilibrium between condensation and evaporation. The feedback-controlled temperature is near or at the dew or frost point and constitutes a measure of humidity.

Three custom circuit boards incorporated into the instrument drive the SAW device at its resonance frequency, provide signal conditioning, and implement digital control and communication.

In addition to the three custom circuit boards, the instrument contains a GPS receiver and an RF modem.

The base station consists of a laptop computer equipped with an RF modem. In addition to serving as a command and control interface as described above, the base station provides a display of real-time data and a moving map with a superimposed mark that represents the position of the instrument.

This work was done by Michael E. Hoenk, Robert Watson, and Greg Cardell of Caltech for **NASA's Jet Propulsion Laboratory.** *For further information, access the Technical Support Package (TSP)* ***free on-line at www.nasatech.com*** *under the Physical Sciences category.*
NPO-20582

Profiling the Atmosphere by Use of an Elevated GPS Receiver

One can estimate the local refractivity of the atmosphere as a function of altitude.

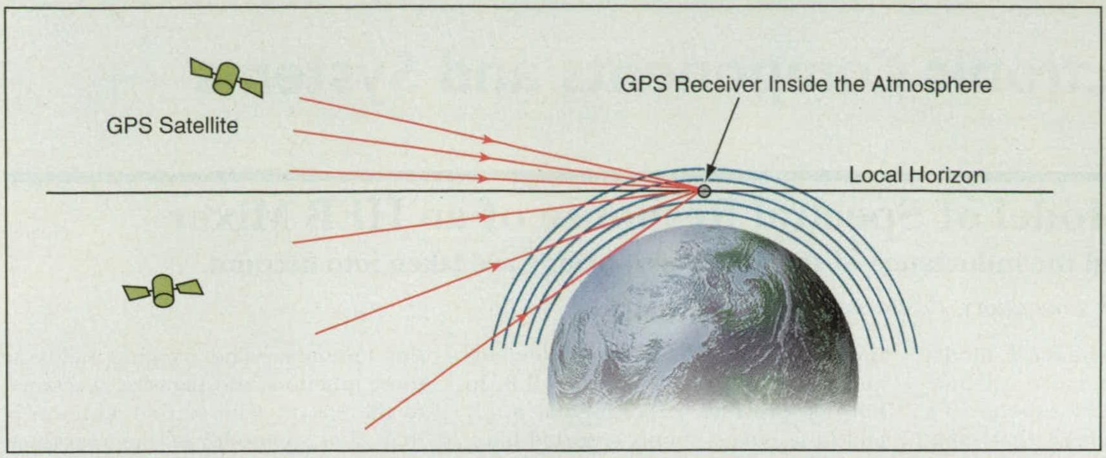
NASA's Jet Propulsion Laboratory, Pasadena, California

A method of determining the radio refractivity of the atmosphere as a function of altitude involves processing of data acquired by airborne or mountain-top Global Positioning System (GPS) receivers from particular GPS satellites as those satellites rise above or fall below the horizon. Previously, data of this type ("GPS occultation data" for short) have been gathered from outside the atmosphere by GPS receivers in low orbits around the Earth and used to generate global refractivity profiles. With the help of temperature data from weather analysis, the refractivity profiles can be converted to water-vapor profiles. In contrast, the present method of utilizing data from GPS receivers located within the atmosphere (see figure) makes it possible to obtain refractivity profiles, and thus water-vapor profiles, that are not global averages and, instead, are averaged over smaller geographic regions wherein the GPS receivers are located. Such higher-resolution water-vapor profiles can be used in studies of regional weather.

For a GPS receiver and a GPS transmitter of interest, the raw GPS data used in the method include the phase delays of the L1 and L2 GPS signals, which are at wavelengths of 19.0 and 24.4 cm, respectively. Other GPS data that are needed in this method include the position of the transmitter of interest, the position of the receiver, and the clock data of the receiver and the transmitter of interest as determined partly from data received simultaneously from other GPS satellites.

By a mathematical derivation that greatly exceeds the scope of this article and that involves a ray-tracing model of propagation of GPS signals through a spherically symmetrical atmosphere, one can find the relationships among the data and other variables. Of particular relevance are the following:

- The relationship between the total bending angle (α) of a GPS ray and the L1 and L2 phase delays;



GPS Occultation Data Are Acquired by a receiver at a known position within the atmosphere.

- The index of refraction (n) of the atmosphere as a function of radius (r) from the center of the Earth [$n(r)$ is the desired information)];
- The parameter a in the equation obtained by applying Snell's law of refraction to a ray propagating through a spherically symmetrical atmosphere [this equation is $nr\sin(\phi) = a$, where ϕ is the local angle between the direction of propagation and the radius vector]; and
- An equation, derived from the preceding equation, that expresses the bending as an integral function of n, r, and a:

$$\alpha = -2a\int_a^\infty \frac{1}{n\sqrt{n^2r^2 - a^2}}\frac{dn}{dr}dr.$$

In this method, the refractivity of the atmosphere is modeled as piecewise exponential with a scale height that changes from one atmospheric layer to the next. The scale heights and a normalizing value of refractivity are retrieved by minimizing, in a least-square sense, differences between (1) bending angles and refractivity determined from GPS data and (2) corresponding quantities obtained from the exponential model and ray-tracing.

The method has been tested by computational simulation for the case of a GPS receiver at an altitude of 5 km. The results of the test have been interpreted as suggesting that the method yields accurate profiles of refractivity at heights ranging from ground level to slightly above the receiver.

This work was done by Cinzia Zuffada, George Hajj, and Robert Kursinski of Caltech for **NASA's Jet Propulsion Laboratory**. *For further information, access the Technical Support Package (TSP)* ***free on-line at www.nasatech.com*** *under the Physical Sciences category.*

NPO-20704

Electronic Components and Systems

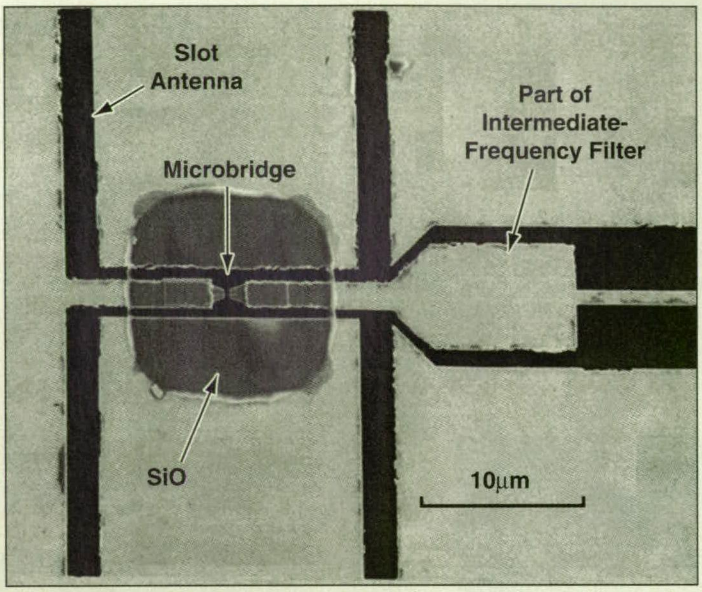
Improved Model of Spectral Response of an HEB Mixer

Fringing fields and the inductance of the HEB microbridge are taken into account.

NASA's Jet Propulsion Laboratory, Pasadena, California

An improved mathematical model enables the somewhat more accurate prediction of the spectral response of a mixer circuit (see figure) that comprises a twin-slot antenna coupled via coplanar waveguides to a hot-electron bolometer (HEB). The development of the improved model is part of a continuing effort to understand and overcome the limitations of circuit models in order to enhance capabilities for designing and analyzing heterodyne mixers to operate at frequencies in the terahertz range.

The improved model was developed in conjunction with, and tested in, experiments that involved measurements of the direct-detection and impedance spectra of HEB mixers that had been designed and predicted, by use of the prior model, for resonance at various nominal frequencies from 0.6 to 2.5 THz. The point of departure for the development of the improved model was a prior model implemented in a method-of-moments computer code. The prior model is a simplified one in that it accounts for the slot antennas and the coplanar-waveguide embedding circuit, but not for the parasitic effects associated with the couplings of these circuit elements and with the geometry of the HEB. In both a previous experimental study and in the experiments reported here, the measured frequencies of peak direct detection response were found to be of the order of 20 percent lower than the resonance frequencies predicted by use of the prior model.



This **HEB Mixer** was designed to operate at a frequency of 2 THz. The HEB is a submicron-size device embodied in the microbridge indicated in the middle.

The improved model is an extension of the prior model, incorporating two major additions: The first addition is that of a submodel of the junctions between the coplanar waveguides and the slot antennas. The fringing fields at these junctions add parasitic reactance to the circuit. The second addition is that of a submodel of the reactance (predominantly inductive) of the very narrow HEB microbridge and of the tapered transition pieces, if any, with which it is connected to the center conductors of the coplanar waveguides. These additions exert a small effect on the real part of the embedding impedance, but a large effect on the imaginary part. The predictions obtained by use of the improved model show that in a typical case, the inductance of the narrow HEB microbridge dominates the estimated shift in the resonance frequency below that of the prior model. However, because the results of the experiments showed that the improved model does not account for all of the observed frequency shift, it is apparent that further refinements of the model are still necessary.

This work was done by Andrea Neto and Rolf Wyss of Caltech for **NASA's Jet Propulsion Laboratory**. *For further information, access the Technical Support Package (TSP)* ***free on-line at www.nasatech.com*** *under the Electronic Components and Systems category.*
NPO-21075

Improved Charge-Termination Technique for Lithium-Ion Cells

Charge/discharge balance is more accurate than that achieved by a conventional technique.

NASA's Jet Propulsion Laboratory, Pasadena, California

An improved charge-termination technique has been developed to obtain a more accurate balance between charge and discharge of rechargeable lithium-ion-based electrochemical cells and batteries. The technique has been demonstrated experimentally and is now in use in a laboratory battery charger. The technique could readily be implemented in the electronic control circuits of battery chargers for consumer electronic equipment.

The conventional charging technique, recommended by manufacturers, involves (1) charging a cell in a current-limited, constant-supply-voltage mode until the cell potential reaches 4.100 V, then (2) allowing the charging current to taper off for about an hour before terminating the charging process. Measurements have shown that

the conventional arbitrary time-based cutoff does not guarantee balance between the amounts of electric charge withdrawn and restored during discharge and recharge, respectively.

In the improved technique as in the conventional technique, one charges a cell in a constant-supply-voltage, current-limited mode. However, instead of terminating the charging process after an arbitrary amount of time, one terminates it when the charging current has decreased to $C/100$ amperes, where C denotes the nominal charge capacity of the cell in ampere·hours. [If the amount of time available for charging is not sufficient for tapering down to $C/100$, then an alternative minimum current (e.g., $C/50$) can be used.] In experiments at operating temperatures from 10 to +40 °C, the $C/100$ cutoff criterion has been demonstrated to return between 0.99 and 1.01 times the amount of charge removed during the previous discharge.

For safety, it would be advisable to augment a $C/100$ charge-termination trigger with a secondary trigger that terminates charging when the charge/discharge ratio reaches 1.01. This secondary trigger would help to prevent further damage in the event that a short circuit develops in the cell, preventing tapering of the charging current.

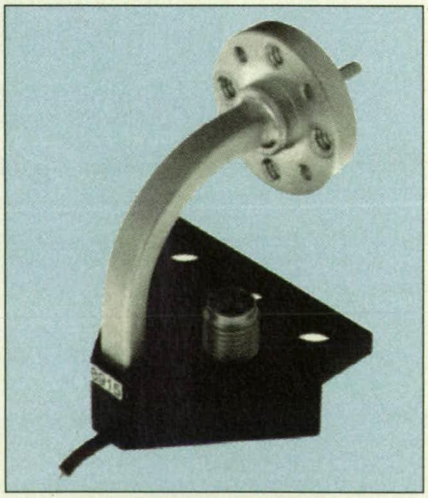
This work was done by David Perrone of Caltech for **NASA's Jet Propulsion Laboratory.** *For further information, access the Technical Support Package (TSP)* ***free on-line at www.nasatech.com*** *under the Electronic Components and Systems category.* *NPO-20358*

Equipment for On-Wafer Testing at Frequencies Up to 220 GHz

Faster circuits can be tested more easily than before.

NASA's Jet Propulsion Laboratory, Pasadena, California

A suite of electronic test equipment has been developed for use in the measurement of key electrical characteristics of advanced, high-speed integrated circuits for communications, radar, digital networks, imaging systems, and other applications. More specifically, the test equipment is designed to enable the determination of noise figures and of scattering parameters (commonly denoted "S" parameters) at frequencies up to 220 GHz. The equipment includes (1) test sets that are basically extended versions of commercial network analyzers that, heretofore, have been functional up to 110 GHz; (2) recently de-



This **Coplanar Wafer Probe** includes a short coaxial probe body coupled to a WR-5 waveguide section for connection to test instruments. The probe is designed for 220 GHz, but the design can readily be extended to >300 GHz.

veloped millimeter-wavelength-signal probes that make it possible to take accurate on-wafer measurements; and (3) an amplifier-based solid-state noise source.

In commercial network analyzers, coverage of frequencies from 50 to 110 GHz is typically accomplished by use of frequency-extension modules that contain multipliers and harmonic mixers. The basic frequency-extender concept is readily applicable to frequencies up to 220 GHz and possibly as high as 325 GHz. Accordingly, the present 220-GHz test sets were developed on the basis of this concept, and were designed to satisfy the following criteria:

- The configuration of the frequency-extension modules must follow accepted industry practice and must be such that one can obtain S_{11} and S_{21} by use of a minimal test system and can obtain all four "S" parameters (S_{11}, S_{12}, S_{21}, and S_{22}) by use of a complete test system.
- The intermediate frequency (IF) use in the test set must be compatible with the most common commercial open-architecture network analyzers.
- The signal radio frequency (RF) and the local-oscillator (LO) drive requirements must be chosen with cost acknowledged as a major design constraint.

Heretofore, in order to measure the electrical characteristics of circuits at frequencies above 100 GHz, it has been necessary to package the circuits into waveguide blocks; this practice is slow and cumbersome, and often does not yield true circuit performance. In contrast, by enabling accurate on-wafer measurements, the recently developed signal probes included in the present test equipment can be expected to foster commercialization by making it possible to characterize circuits accurately, in rapid succession, at relatively low cost.

The figure depicts one in a line of coplanar probes designed for testing millimeter wave circuits. The probe tips, made of beryllium-copper, are individually spring-loaded for reliable connections even to nonplanar circuit structures. A bias T is included to provide current (up to 1.5 A) to the circuit under test and includes loss elements to absorb signals below the waveguide cutoff frequency (115 GHz in this case), where the waveguide becomes highly reflective. Special miniaturized coplanar calibration substrates have been developed for use with this and the other probes.

In tests of a receiver circuit, it was found to be cumbersome to perform noise measurements by use of alternate hot and cold loads in front of a feed horn attached to a wafer probe. Therefore, a transfer standard was constructed: An amplifier with a frequency range of 150 to 190 was packaged into a waveguide block. With its input terminated and its output attenuated to provide a stable output impedance, the amplifier proved to be an ideal semiconductor noise source with an excess-noise ratio of 10 dB. The estimated error in the noise figure measurement is less than 1 dB.

The use of the amplifier as a noise source makes it possible to use a commercial noise-figure meter as an IF processor. This, in turn, enables optimization of biases of circuits under test. In contrast, optimization of bias during testing with hot and cold loads has proved to be a tedious task that has yielded inaccurate results.

This work was done by Todd Gaier and Lorene Samoska of Caltech, Charles Oleson of Oleson Microwave Labs, and Greg Boll of GBB Industries for **NASA's Jet Propulsion Laboratory.** *For further information, access the Technical Support Package (TSP)* ***free on-line at www.nasatech.com*** *under the Electronic Components and Systems category.*
NPO-20760

Software

Software for Ground Operations for a Prototype Mars Rover

A software system has been developed for use in Earth operations centers communicating with a robotic exploratory vehicle (rover) on Mars. The software was designed for and field-tested on the Field Integrated Design and Operations rover — a prototype similar to rovers of the planned 2003 Mars Explorer Rover mission. The software subsystems and their functions include the following: (1) The Parallel Telemetry Processing (PTeP) system processes downlink data and stores data products in a database. (2) The Multi-mission Encrypted Communication System (MECS) provides communication between a primary terrestrial operations center and geographically distributed, Internet-based users. (3) The Web Interface for Telescience [WITS (aspects of which have been described in several prior *NASA Tech Briefs* articles)] displays information downlinked from the rover — video images from several rover cameras and alphanumeric data. Data are coregistered, and uplink targets are coregistered with downlink data. The WITS enables geographically dispersed users to collaborate in the generation of a sequence of commands to be uplinked to the rover, assisting the collaboration by analyzing resources, checking for adherence to rules, automatically correcting errors in the sequence, and predicting (through simulation) the states of the rover at various points in the sequence.

This program was written by Paul Backes and Jeffrey Norris of Caltech for **NASA's Jet Propulsion Laboratory**. *For further information, access the Technical Support Package (TSP)* ***free on-line at www.nasatech.com*** *under the Software category.*
NPO-21235

Software Processes SRTM ScanSAR Data Into Topographical Maps

A computer program automatically generates topographical maps from data collected by scan-mode synthetic-aperture radar (scanSAR) during the Shuttle Radar Topography Mission (SRTM). A preprocessing subprogram subdivides the SAR data, along with ancillary spacecraft-motion, control, and calibration data, into latitude bands called peg regions and puts out the data in a coordinate system and format appropriate for a processing subprogram. The main function of the processing subprogram is to generate strip maps from the preprocessed data, by use of an algorithm developed previously for airborne interferometric SAR mapping and modified to accommodate the burst mode of collection of SAR data of the SRTM (each burst nor-

mally comprising between 50 and 80 pulses). The SAR burst mode stands in contrast to the traditional SAR strip mode, in which every target is illuminated for the entire along-track width of the radar beam. The processing subprogram generates burst-level interferograms, then combines interferograms from multiple bursts in such a way as to generate accurate topographical maps. Results of processing thus far indicate that the program is working as intended and confirm the expectation that the program will generate the first globally consistent digital elevation map of the Earth.

This program was written by Scott Hensley, Paul Rosen, and Eric Gurrola of Caltech for **NASA's Jet Propulsion Laboratory**. *For further information, access the Technical Support Package (TSP)* ***free on-line at www.nasatech.com*** *under the Software category.*

This software is available for commercial licensing. Please contact Don Hart of the California Institute of Technology at (818) 393-3425. Refer to NPO-21205.

Algorithm for Autonomous Visual Discovery

An algorithm that can discover potentially interesting objects in image data has been formulated and implemented in software. The algorithm is intended for applications in which the target objects are mathematically ill-defined and/or not known or specified in advance. Potential applications include finding localized geological features, locating defects in fabrics, and identifying fossils in rock samples. The algorithm, which is based loosely on the human visual system, looks for regions of the image that differ significantly from the local background context. Regions of the image are projected into a subspace by use of multi-orientation, multi-scale Gabor filters. Within this filter-response subspace, deviant areas are identified by use of an adaptive statistical test in which the filter-space description of the region is compared with a mathematical model derived from the local background. Deviant areas are then spatially agglomerated and grouped across scale. In preliminary computational experiments on planetary images collected with various instruments (optical cameras, imaging radar, and ground-based telescopes), the software, without specifically being told what to look for, was able to autonomously rediscover a number of well-known geological features, including impact craters, volcanoes, dunes, and ice geysers.

This program was written by Michael Burl, Charles Fowlkes, and Dominic Lucchetti of Caltech for **NASA's Jet Propulsion Laboratory**. *For further information, access the Technical Support Package (TSP)* ***free on-line at www.nasatech.com*** *under the Software category.*

This software is available for commercial licensing. Please contact Don Hart of the California Institute of Technology at (818) 393-3425. Refer to NPO-21107.

Computer Program Generates Test Cases

An Automated Test Case Generator computer program generates parameter-based test cases for testing software and hardware systems. Given *N* parameters — each of which represents a kind of variation for testing — and a finite set of possible values for each parameter, the program generates individual test cases by selecting a value for each parameter. Collectively, test cases cover the space of possible combinations to a degree specified by the user. The pro-

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gram selects parameter values according to a combinatorial design that generates a near-minimum number of test cases to afford the user-specified coverage. The program is especially suitable for systems having a large number of value combinations in which there is a need for a user-specified degree of coverage in a relatively small test suite. An evaluation on test parameters from the Deep Space One mission revealed that this program generated fewer test cases than did a prior test-case-generator program. The performance of this program is comparable to that of an Internet-based service called AETG. However, unlike AETG, this program uses a purely deterministic algorithm, is amenable to modification by the user, and can be incorporated into other programs.

This program was written by Yu-Wen Tung, Daniel Dvorak, Eugene Chalfant, and Wafa Aldiwan of Caltech for **NASA's Jet Propulsion Laboratory**. *For further information, access the Technical Support Package (TSP)* ***free on-line at www.nasatech.com*** *under the Software category.*

This software is available for commercial licensing. Please contact Don Hart of the California Institute of Technology at (818) 393-3425. Refer to NPO-21195.

Software Manages Documentation in a Large Test Facility

The 3MCS computer program assists an instrumentation engineer in performing the 3 essential functions of design, documentation, and configuration management of measurement and control systems in a large test facility — initially, a propulsion-system test facility at Stennis Space Center. By largely automating what were previously manual procedures involving handling of paper documents by disparate personnel, 3MCS helps to reveal and prevent errors while reducing, from days to hours, the time needed to transform test requirements into design documents (including drawings) and work orders. Among the services provided by 3MCS are acceptance of input from multiple engineers and technicians working at multiple locations; standardization of drawings; on-line distribution of the most recent versions of drawings and other documents to all participants; automated cross-referencing, identification of errors, and listing of components and resources; automated downloading of test settings; and provision of information to customers. 3MCS is designed to be executed on personal computers. It utilizes and depends on some commercially available computer programs, including Windows 98/NT, AutoCAD 2000, Promis-e, Microsoft Office 2000, and some utility and virus-detection software.

This program was written by Joseph M. Gurneck of Lockheed Martin for **Stennis Space Center**.

Inquiries concerning rights for the commercial use of this invention should be addressed to the Intellectual Property Manager, Stennis Space Center; (228) 688-1929. Refer to SSC-00122.

Software Performs Testing, Monitoring, and Control Functions

The Front End Processor (FEP) Real-Time Embedded Software performs command and data-processing functions for an aeronautical MIL-STD-1553B telemetry link and ground support equipment (GSE) in a spacecraft-equipment-testing environment. The FEP is used in the Test, Control, and Monitor System of the Space Station Program for checking out Space-Station modules and payloads as they flow through Kennedy Space Center. Consisting of about 50,000 lines of C-language code, the FEP software runs on Motorola MVME 167 processors in a VersaModule Eurocard (VME) chassis. The software can be recompiled for execution on other processors. The software interacts with the 1553B telemetry link through commercial VME interface cards and supports as many as four redundant 1553B buses. The GSE interfaces consist of analog, digital, relay, and serial links for controlling the GSE used in testing. The software includes modules that control and monitor the MIL-STD-1553B links of the Space Station and the associated GSE interfaces. Back-end interfaces (user interfaces) to the FEP software are provided through a standard Ethernet network that enables a user or a testing application program to exercise control or to monitor data from the interfaces supported by the FEP software.

This program was written by Thomas L. Herring, Richard B. Arnold, Christopher S. Forney, Eric J. Schafer, Berta A. Alfonso, Wyck C. Hebert, Jeffrey S. Vickers, Pamela A. Meier, Jose A. Marin, Andrew E. Wheeler, and Chau B. Lee of **Kennedy Space Center**. *For further information, access the Technical Support Package (TSP)* ***free on-line at www.nasatech.com*** *under the Software category.*
KSC-12122

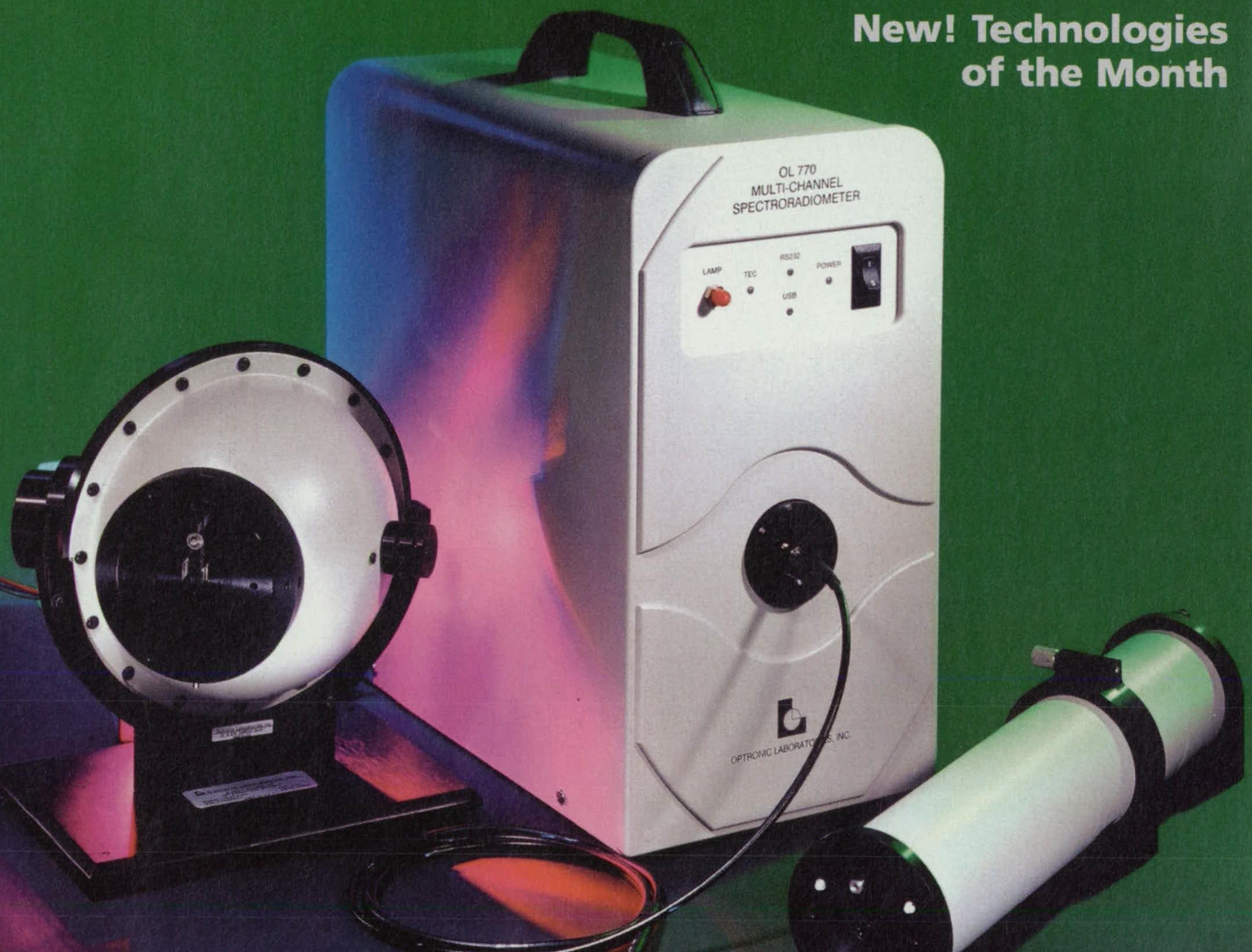
November 2001

PHOTONICS Tech Briefs

PHOTONICS SOLUTIONS FOR THE DESIGN ENGINEER

The Search for the All-Optical Switch

New! Technologies of the Month



New Products — see page 30a

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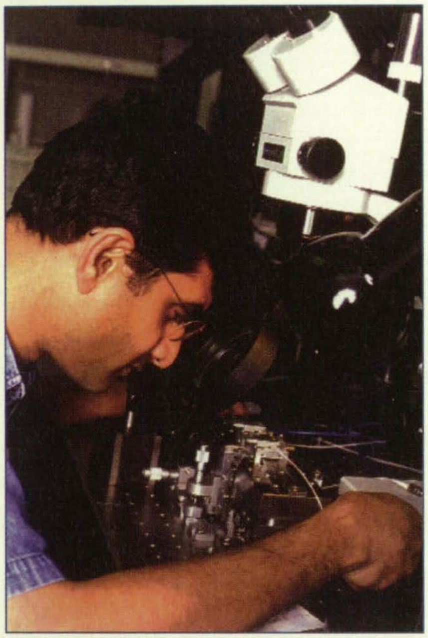
On the cover: *Optronic Laboratory's OL 770-LED CCD-based multichannel spectroradiometer.*

Cover photo courtesy of Optronic Laboratory Inc.

The Search for the All-Optical Switch

As the demand for bandwidth grows, the industry races to find better and faster switching and other technologies.

It is a peculiar moment in the life of fiber optic technologies related to communications. Potential customers face a glut of bandwidth for the current traffic, but no one doubts that demand will someday catch up with supply, as Internet telephony and web use, computer-to-computer communications, streaming digital video and audio, and other services grow in volume. According to sources at Corning Inc., demand for bandwidth is expected to grow at an average rate of more than 100 percent per year for the next 10 to 15 years.



Radiant Photonics' optics lab

But with so much existing fiber optic cabling, new instrumentation is required to get that cabling to yield increased bandwidth. Most of the existing system uses optical fiber for long-distance transmission, but the light signals must be converted to electrical signals for switching and amplification. This process is costly, and limits the bandwidth the systems can carry. So the industry is searching for technologies that can do away with the electrical repeaters and meet bandwidth demands with all-optical systems.

One approach to the problem is wavelength division multiplexing (WDM), by which multiple optical signals are transmitted on a single fiber strand. This process has increased the amount of information carried on a fiber from between 1 and 2.5 gigabits per second (Gb/s) to between 10 and 40 Gb/s, the latter capacity just now reaching the newest installations. Researchers are also working on 400 Gb/s carriers.

But carriers cannot realize these gains with the existing electrical equipment that routes signals. Existing switches cannot deal with throughput above 2.5 Gb/s. So many companies in the industry are striving to be the first to develop an all-optical-core switch that can route signals without the assistance of electrical switches.

One source of funds for such development is the Ballistic Missile Defense Office (BMDO) and its Small Business Innovation Research department (SBIR). This agency's interest is in battlefield communications, where data is collected, interpreted, and communicated to various military systems, enabling complex battle management decision-making. Synchronization between multiple and sometimes distant ground and air subsystems is required, and response times must be the fastest possible.

Several companies are building solid-state optical-core photonic switches that do not rely on an electrical impulse, changing a signal's direction based on its wavelength or polarization. Radiant Photonics of Austin, TX, has developed a model switch that is insensitive to polarization differences or slight variations of wavelength in incoming signals, thereby eliminating costly correcting equipment. It is based on polymers used in thermo- or electro-optic prisms. These prisms can vary the index of refraction in response to temperature or an input voltage. The device determines where a signal hits a diffraction grating, and thus controls which output fibers the signal will reach. Doping the gelatin used in the prisms gives them their refractive characteristics. Radiant's switch can operate equally well in the C, L, and S communications bands, and provides response speeds of just 1 nanosecond (compared with 10-15 milliseconds for competing technologies), and has an insertion loss of less than 1 decibel.

Other companies are developing polymer switches, too, but most rely on complicated phase delays, and are thus sensitive to polarization differences and wavelength variations. Radiant's switch would do without more expensive lasers and correcting equipment. It also would have faster response times than micromechanical switches, also under development. It could have as many as 50 output channels. BMDO funded the work because it needed a polymer for high-speed fiber optic components that could withstand the temperatures of airborne and spaceborne applications.

Meanwhile, SpectraSwitch Inc. of Santa Rosa, CA, has patent-pending technology for using liquid crystal as the switching medium. Its WaveWalker™ components include a low-port-count photonic switch called the WaveWalker 1 × 2, used in single-mode transmission in an all-optical network. The company's switch uses liquid crystal and birefringence — the ability to refract unpolarized light into two separate orthogonally polarized rays — with the material's response to an electric field. A liquid crystal cell rotates the polarization of incoming light when a voltage is applied. SpectraSwitch's device is one of the fastest-switching under development, reducing the current optomechanical industry standard from 10-15 milliseconds to less than 4. Because the material is rugged and immune to vibration degradation, the company claims it will have a billion-cycle durability. SpectraSwitch expects to develop a full line of WaveWalker components, including variable optical attenuators, optical add/drop multiplexers, polarization mode dispersion compensators, and multifunctional modules. The technology was funded in part by BMDO.

Another company using liquid crystal technology is Chorum Technologies of Richardson, TX. The company has developed its PolarWave commercial line from its technology, consisting of a fast add/drop switch and a 1 × 2 switch. The devices use a patented fault-tolerant architecture to achieve crosstalk and insertion loss numbers comparable to the optomechanical specifications now in use. The switch is suited to network protection and restoration applications that require highly reliable switching with response times in the millisecond domain.

Chorum's switch uses polarization manipulation to provide the basis for switching with no moving parts. Its complimentary polarization design allows for a high polarization extinction ratio made possible by the use of liquid crystal. And a method for eliminating unwanted optical energy yields a crosstalk

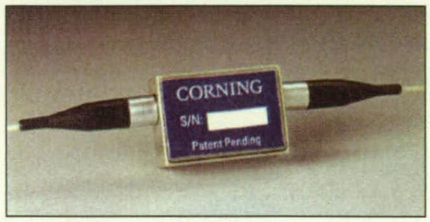
figure of less than -45 dB and an insertion loss of less than 1.3 dB. The PolarWave line will also include optical filters, optical processors, and integrated optical subsystems. BMDO awarded Chorum an SBIR Phase II contract to develop a state-of-the-art switch for its optical signal processing applications.

OptiComp Corp. of Zephyr Cross, NV, has developed an optoelectronic logic-array-based distributed crossbar switch that provides terabit-level end-to-end throughput. This SmartCross™ crossbar switch can be integrated into networks of all kinds that use the 1.3-micron wavelength standard, reducing central switching requirements in datacom and telecom networks. The distributed crossbar supports high levels of fan-in and fan-out switching. The company plans a range of components and subsystems using the crossbar technology, targeted for integration into long- and short-distance networks. Specifications for beta-site testing have been solicited from industrial partners. BMDO funds supported the production of cost-effective 1.3-micron VCSELs for massive parallel optical interconnects.

At another California company, Templex Technologies of San Jose, an optical encoding and decoding technology based on fiber Bragg gratings has been developed that would increase the optical throughput in a metro-access network and minimize the need for costly routing equipment. The company expects a hundredfold increase in the efficiency and capacity of today's networks. Called SmartFBG™, the product is aimed at the market for ultra-narrow channel-spacing dense wavelength division multiplexing. Templex bases its expectations on a passive all-optical routing and switching protocol using complex gratings about the size of a microscope slide.

The gratings are formed by producing complex periodic variations in the index of refraction of the glass lengthwise along a fiber. The grating is designed so that the refractive index modulation causes light of a specific wavelength. This makes it useful for separating and switching signals, and also for putting an optical code on every pulse of light. When a short pulse is reflected by the grating, the light is reshaped, delayed, and stretched into a uniquely coded pulse. The temporal shape of this optical signal can then be used for multiplexing and demultiplexing information, thereby eliminating electronic conversion. Templex's optical code division multiplexing is the only coding technology that is full compatible with dense wavelength division multiplexing. BMDO supported Templex with a two-year FasTrack Phase II SBIR contract to pursue novel switching and control devices for all-optical networking.

Yet another California company, BroaData Communications of Torrance, is marketing a series of duplex multimedia extenders using a crossbar technology that allows simultaneous transmission of audio, video, and data content along one fiber. The optoelectronic crossbar combines signal fan-out and fan-in operations with electronic modulation of laser sources. It comprises three plane modules that can be stacked on each other to



Corning Applied Technologies' polarization controller

produce a very compact device. The crossbars, with switching speeds ranging from 0.1 to 30 microseconds, are compatible with fiber optic communications standards. Other applications include high-speed signal switching, reconfigurable networks, and signal multiplexing. BMDO's SBIR program underwrote this technology to provide fast, reconfigurable networks and to improve computer communication systems.

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Optical Acceleration Sensor for Highly Sensitive Acceleration and Vibration Measurement

An acceleration measurement system on an optical basis is presented. Low weight, high sensitivity, and excellent EMC compatibility are its primary properties. The sensor is highly sensitive due to its particular micromechanical design. Multiple sensors can be arranged on a single sensor line, and their signals can be discriminated. An excellent EMC/ESD compatibility is provided since no metallic parts are involved, either in the sensor or in the transmission line. Moreover, the fiber optic technology allows highly insulated measurement. Multiple acceleration measurement and vibration detection are the preferred applications.

This invention presents a new type of Bragg grating acceleration and vibration sensor. A micromechanical structure allows acceleration measurements with lower inert mass than known Bragg acceleration sensors. The high sensitivity of the sensor is achieved by a compact mechanical lever in the structure. An inert mass is attached to the lever that moves in the plane of the structure. When accelerated, the lever stretches a fiber grating. Two overlapping gratings move in opposite directions, which results in an intensity modulation of back-reflected light with excellent temperature compensation and a high sensitivity. By means of different wavelengths several sensors can interrogate on one optical fiber line.

For more information go to
www.yet2.com/PSUser/special.htm?c=1240&l=51&cid=27815

Laser Sensor for Weld Seam Tracking

The laser vision sensor is a modern noncontact weld seam tracking system. The sensor uses a visible (red) laser to illuminate the weld joint. The laser is viewed through a very narrowband optical filter by a high-resolution CCD camera. The filter removes any light not at the laser frequency, including any arc light. The system is completely unaffected by the welding arc as long as the arc is not directly in the sensor's field of view. In practical terms, the sensor looks ahead of the arc a short distance. The video signal is digitized in the sensor and sent to the vision controller. Suitable corrections are output to the slides.

The laser vision sensor is to track weld lines for adaptive gas metal arc welding and submerged arc welding. The specific application is circumferential multipass/multilayer girth welding and longitudinal welding.

For more information go to
www.yet2.com/PSUser/special.htm?c=1240&l=50&cid=27815

Tunable Ultraviolet Light Source for Combustion Experiments

The source enables simultaneous WMS and LIF measurements for quantitation of trace gas species.

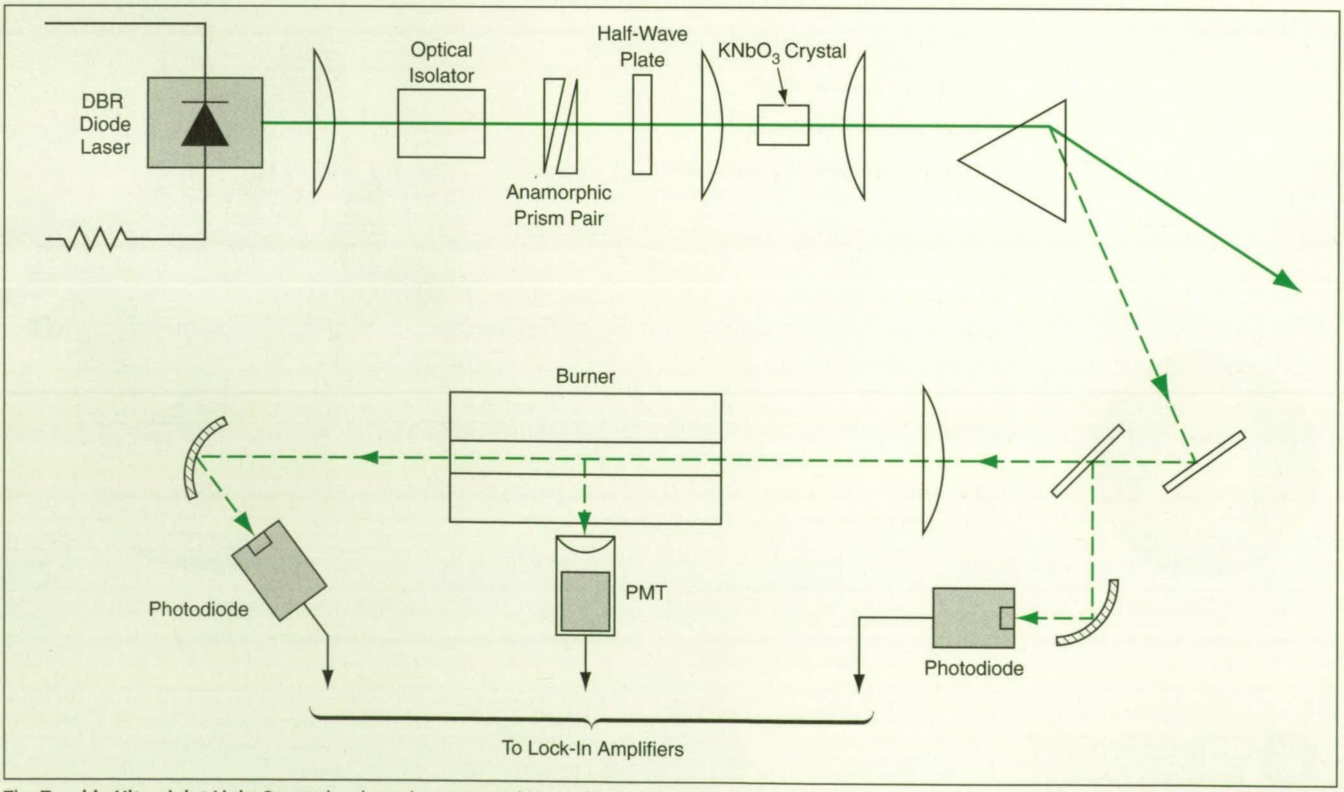
John H. Glenn Research Center, Cleveland, Ohio

An ultraviolet light source that comprises a tunable diode laser and associated optics provides the optical excitation needed for simultaneous wavelength-modulation-absorption spectroscopy (WMS) and laser-induced-fluorescence (LIF) measurements in experiments on combustion. These measurements are needed for determining the spatially and temporally resolved concentrations of molecular and radical species that play important roles in flames. Other uses for measurements of this type could include general detection and quantitation of trace gases in the atmosphere, including toxic gases emitted by industrial facilities. Instruments that incorporate light sources like the present one and that will perform these measurements are undergoing development. In comparison with prior ultraviolet lasers and with prior WMS and LIF instruments, the present light source and the developmental instruments are compact and rugged and consume less power. As a result, the developmental instruments are expected to be suitable for use, not only in laboratories, but also in diverse harsh environments, including those of drop towers, aircraft, and spacecraft.

Heretofore, WMS and LIF measurements have been performed separately. WMS enables highly sensitive detection and quantitation of trace molecular and radical species. However, because it involves integrated absorbance along a laser beam, it yields no information on the spatial distribution of species. LIF measurements taken along lines of sight perpendicular to a laser beam can be used to map relative densities of species as functions of position along the line of sight. However, it is extremely difficult to obtain absolute density information from LIF data because of a need for careful calibration of laser intensity and geometric factors and mathematical modeling of fluorescence quenching by collision partners. By suitable processing of WMS and LIF data acquired simultaneously by the developmental instruments, it should be possible to eliminate the difficulties associated with geometric factors and laser-intensity fluctuations, thereby facilitating the determination of absolute density distributions.

The figure is a simplified schematic depiction of the present light source as part of a prototype apparatus for probing a hydrocarbon flame with simultaneous WMS and LIF measurements in a wavelength band centered about 426 nm. This wavelength band is associated with CH radicals, which play a major role in combustion of hydrocarbons. Pump light at a wavelength of ≈852 nm, with a power of ≈120 mW, is generated by a distributed-Bragg-reflector (DBR) diode laser. The laser beam is collimated and circularized by an anamorphic prism pair. The beam is then focused into a 7-mm-long A-cut $KNbO_3$ crystal, which is optically nonlinear and thus serves to convert some of the laser power to the second harmonic, which is at the desired wavelength of ≈426 nm. An optical isolator between the diode laser and the frequency-doubling $KNbO_3$ crystal minimizes feedback of reflected light to the laser diode. A half-wave plate, also between the diode laser and the $KNbO_3$ crystal, matches the polarization of the pump beam with the orientation of the crystal.

The $KNbO_3$ crystal is mounted on a thermoelectric cooler in an N_2-purged housing for temperature-tuned noncritical phase-matching operation at a temperature near 10 °C. The 426-nm beam



The **Tunable Ultraviolet Light Source** has been incorporated into a laboratory apparatus used to demonstrate the feasibility of simultaneous WMS and LIF measurements to determine distributions of CH radicals along a line defined by a laser beam.

is collimated and separated from the residual 852-nm pump beam by use of a CaF_2 prism. The frequency of the residual pump beam is monitored to within 0.01 cm^{-1} by use of a scanning interferometer. When the 852-nm power input to the crystal is 85 mW, the 426-nm output power is 100 μW. This output ultraviolet power is stable as long as the temperature of the crystal is stabilized to within ±0.1 °C.

The wavelength of the beam generated by the laser diode is tuned by adjustment of its temperature and injection current. The injection current is modulated at a frequency of 50 kHz to produce wavelength modulation of the frequency-doubled beam. A linear current sweep is also applied to the diode laser, to tune the center frequency across the absorption spectral line of interest during wavelength modulation.

For laboratory feasibility measurements, the 426-nm beam is directed along the flame front of a slot burner. For the purpose of WMS, the intensity of the beam after transmission through the flame is monitored with a silicon positive/intrinsic/negative (PIN) photodiode, the output of which is sent to a lock-in amplifier for detection at a frequency of 100 kHz. A blue-pass filter (not shown in the figure) in front of the photodiode reduces the incident visible and near-infrared flame luminescence. Second-harmonic CH absorption spectra are acquired by detection of the transmitted beam while the frequency is repetitively swept across the absorption spectral line. The second-harmonic signals are calibrated against direct (unmodulated) absorbance measurements.

For LIF measurements, a lens images a 2-mm segment of the region illuminated by the laser beam onto a photomultiplier tube (PMT). A 431±1-nm band-pass filter suppresses flame-luminescence light while passing CH-fluorescence light to the photomultiplier. The output of the photomultiplier is sent to a lock-in amplifier for phase-sensitive detection of LIF at a sampling frequency of 100 kHz. (Additional experimental details and measurement results are found in K. A. Peterson and D. B. Oh, *Optics Letters*, vol 24, pp 667-669.)

This work was done by Daniel B. Oh and Kristen A. Peterson of Southwest Sciences, Inc., for **Glenn Research Center**.

Inquiries concerning rights for the commercial use of this invention should be addressed to NASA Glenn Research Center, Commercial Technology Office, Attn: Steve Fedor, Mail Stop 4–8, 21000 Brookpark Road, Cleveland, Ohio 44135. Refer to LEW-17120.

Fourier-Transform X-Ray Microscope

High-resolution maps of chemical-element abundances and chemical bonds could be generated.

NASA's Jet Propulsion Laboratory, Pasadena, California

A proposed x-ray instrument — a Fourier-transform x-ray microscope — would enable high-resolution imaging of objects with sizes of the order of 20 nm. (This size range is typical of cell organelles.) The instrument would also offer a spectroscopic capability for the sensitive detection and identification of selected chemical elements and chemical bonds. The instrument could be used, for example, to examine microscopic biological samples, to study surface chemistries, or to identify chemical contaminants on the surfaces of microelectronic devices during fabrication.

Heretofore, information of the sort that the proposed instrument would provide has been obtained through (1) imaging of photoelectrons excited by illumination with a monochromatic beam of soft x-rays from a synchrotron x-ray source or (2) transmission microscopy with monochromatic radiation, also from a synchrotron source. The disadvantage of both techniques is that a large apparatus (a synchrotron) is needed to produce sufficient fluxes at the wavelengths of interest. The Fourier-transform function of the proposed instrument would exert an effect equivalent to multiplying the flux density of x-rays by a factor of the order of 103; this effect would make it possible to use a smaller, electron-beam-based x-ray source. Consequently, unlike x-ray imaging systems based on synchrotron sources, the proposed system would be amenable to miniaturization.

The proposed instrument (see figure) would include an electron-beam-based x-ray source with an output spectrum spanning a wavelength band (1) approximately centered at an absorption edge of a chemical element of interest and (2) broad enough to include possible chemical shifts (± about 10 eV). Two examples of such a wavelength band are 284.3±10 eV for C or 346.2±10 eV for Ca.

A Mach-Zender interferometer would modulate the spectrum with a period of about $2\pi\Delta x/c$ in frequency (where Δx is the difference between the lengths of the two optical paths in the interferometer and c is the speed of light). By use of a microactuator, the mirrors in the interferometer would be moved to vary Δx by small increments. A specimen would be illuminated by the x-ray beam coming out of the interferometer. X rays reflected from the specimen would be imaged on a scintillator, which would convert the x-ray image to a visible one that, in turn, would be acquired by a charge-coupled-device (CCD) camera.

An image would be acquired at each Δx. The image data acquired over all of the many small increments of Δx would be Fourier-transformed and otherwise processed to obtain x-ray spectra for the pixels in the image. From the magnitudes and shifts of absorption edges in these spectra, high-resolution atomic-concentration and chemical-bonding maps of the chemical element of interest could be generated.

This work was done by Kirill Shcheglov and Victor White of Caltech for **NASA's Jet Propulsion Laboratory**. *For further information, access the Technical Support Package (TSP)* ***free on-line at www.nasatech.com*** *under the Physical Sciences category.*
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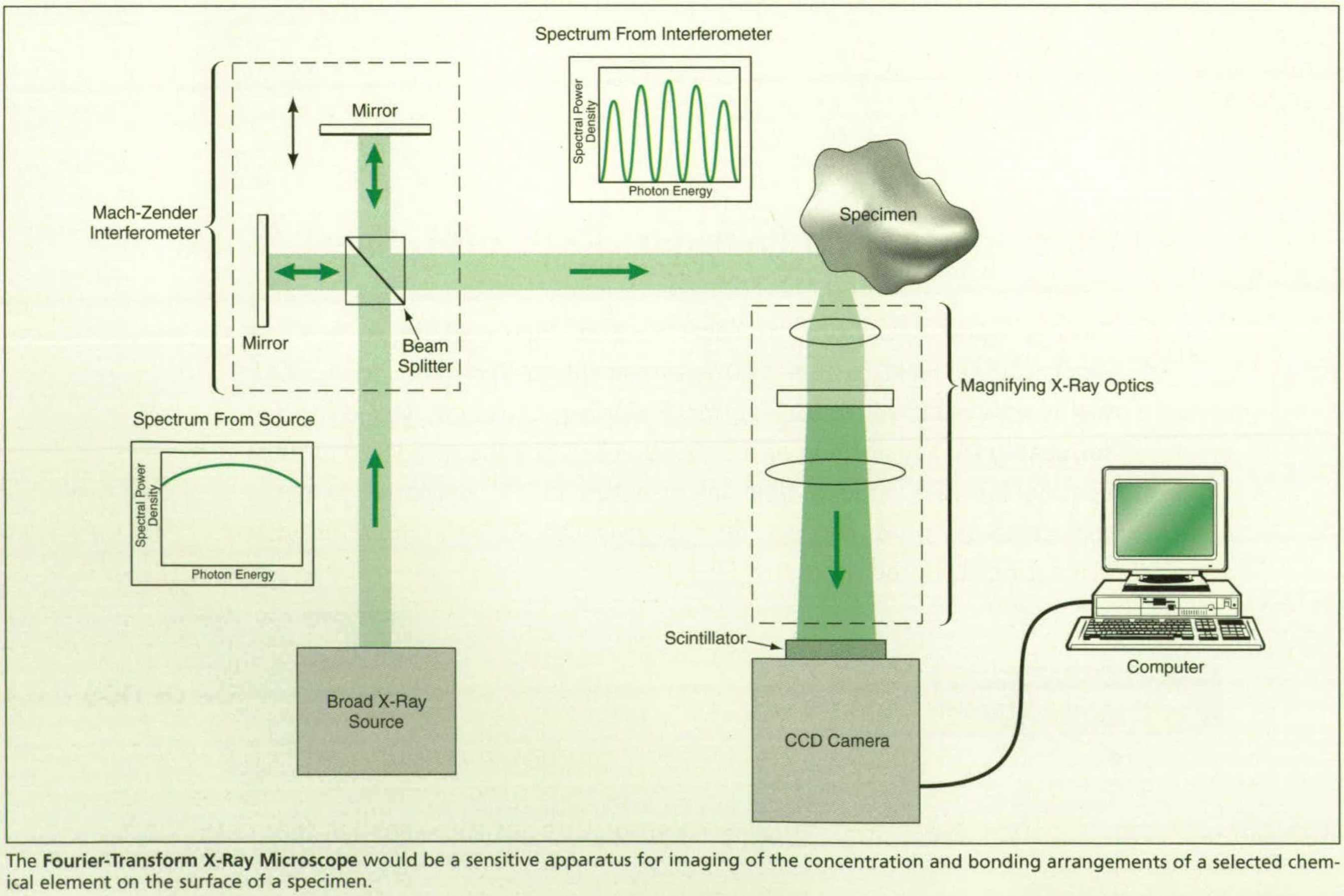
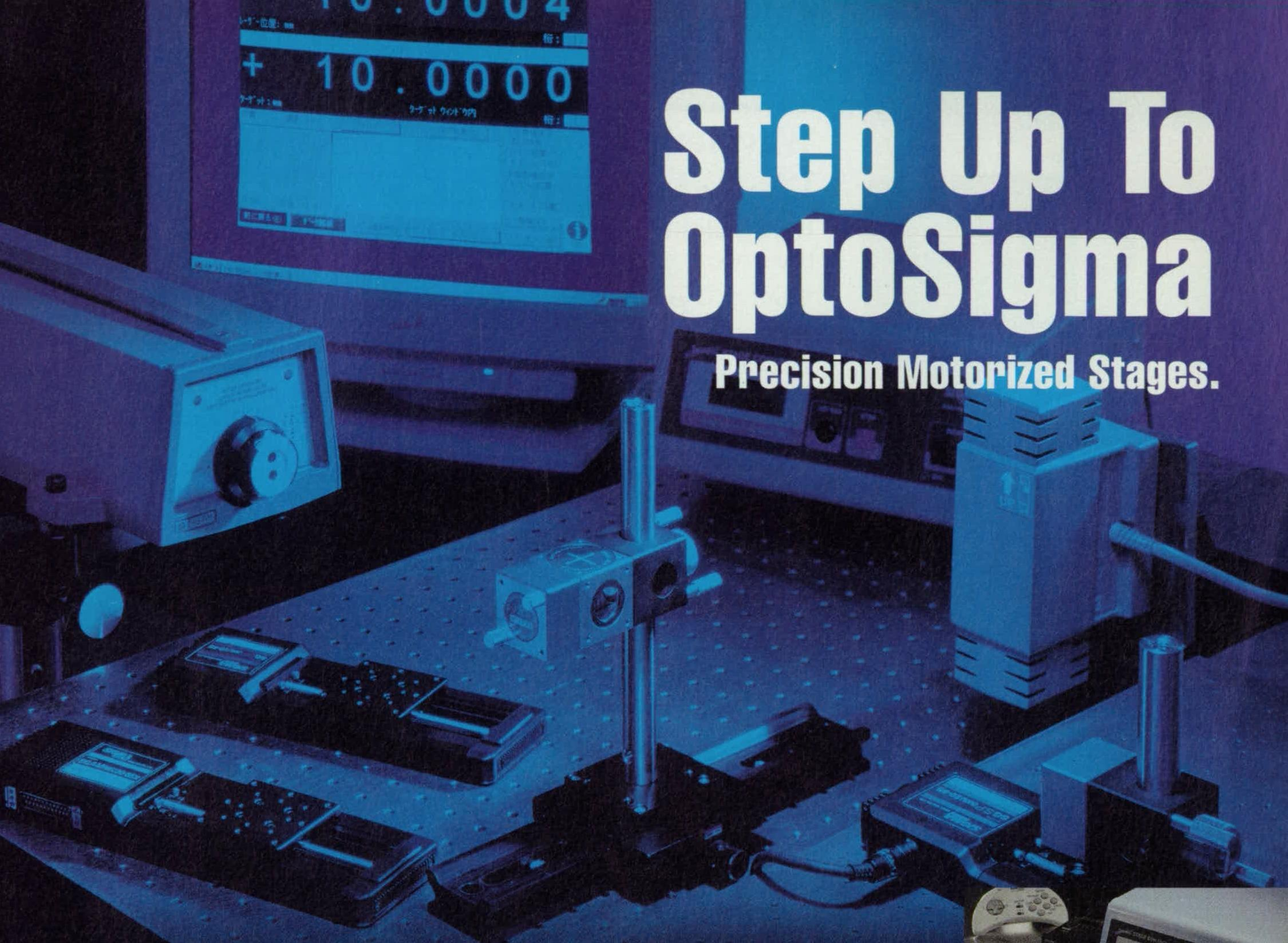
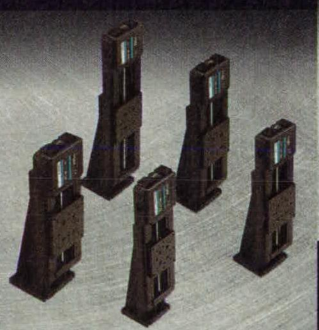
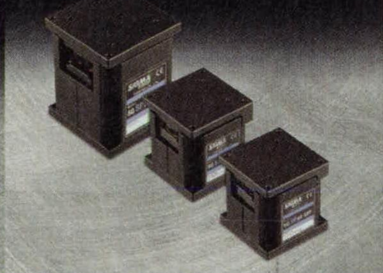


The **Fourier-Transform X-Ray Microscope** would be a sensitive apparatus for imaging of the concentration and bonding arrangements of a selected chemical element on the surface of a specimen.







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Wavelength-Agile External-Cavity Diode Laser

Both stability and wavelength agility are attainable at relatively low cost.

John H. Glenn Research Center, Cleveland, Ohio

A prototype wavelength-agile external-cavity diode laser (ECDL) was demonstrated in the first phase of a continuing effort to develop noninvasive laser-based instruments that would measure absolute concentrations of trace gases. As envisioned, these instruments would offer a combination of high sensitivity, versatility, large bandwidth, long-term stability, accuracy, and reliability — attributes that would make them attractive for use in research on combustion.

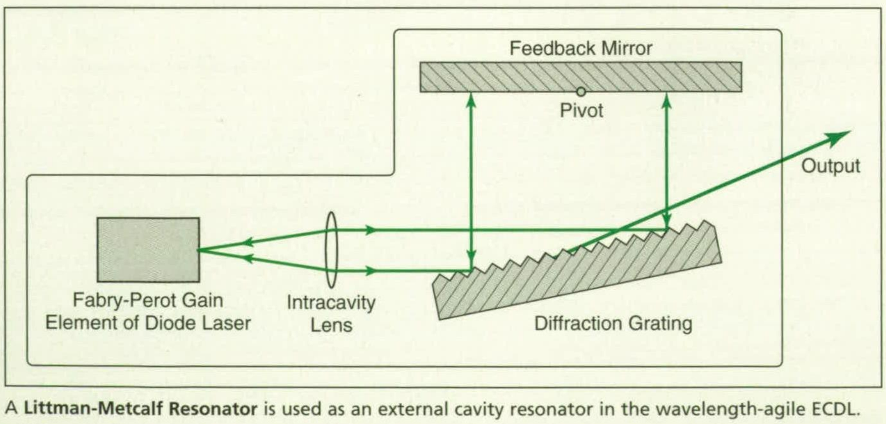
The measurement principle to be implemented in the developmental instruments is that of wavelength-modulation spectroscopy (WMS). ECDLs are useful for detecting trace gases by WMS because their wavelength-tuning ranges are greater than those of diode lasers alone and, consequently, it is generally practical to design and operate an ECDL such that an absorption spectral feature characteristic of a molecular species that one seeks to detect lies within the nominal tuning range of the ECDL. In prior ECDLs, wavelength modulation is effected by using piezoelectric actuators to translate laser optics. This mechanical-translation approach limits achievable modulation frequencies to a few kilohertz, whereas frequencies of tens or even hundreds of kilohertz are needed to enable the use of high-sensitivity detection techniques in WMS. In addition, prior commercially available ECDLs include complex and expensive optical components.

The present prototype ECDL (see figure) is simple and inexpensive, relative to prior commercial ECDLs. Its design combines the stability of an external-cavity laser with the wavelength agility of a diode laser. The design allows for wavelength modulation of the ECDL by modulation of the diode gain element injection current. The external cavity is of a type known in the art as a Littman-Metcalf resonator, in which the zeroth-order output from a diffraction grating is used as the laser output and the first-order-diffracted light is retroreflected by a cavity feedback mirror, which establishes one end of the resonator. The other end of the resonator is the output surface of a Fabry-Perot resonator that constitutes the diode-laser gain element. Wavelength selectivity is achieved by choice of the angle of the diffracted return beam, as determined by position of the feedback mirror.

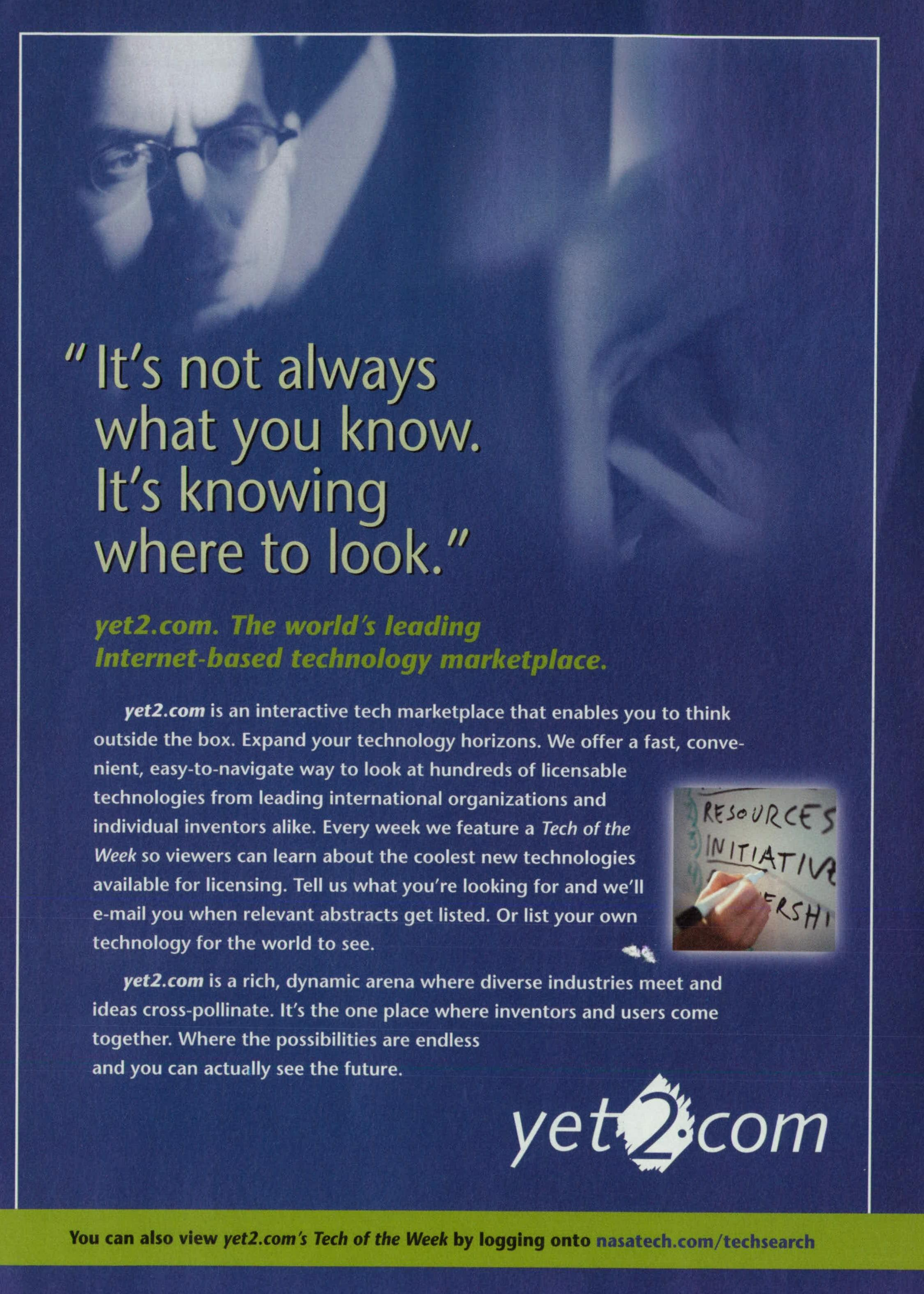
The diode laser in the prototype wavelength-agile ECDL is of a room-temperature ultraviolet type that has recently become commercially available. However, the design principle is just as well adaptable to other diode lasers. The feasibility of the developmental instruments has been demonstrated by using the prototype wavelength-agile ECDL as the source of light in a prototype WMS spectrometer for measuring concentrations of CH radicals in laboratory flames.

This work was done by Jeffrey S. Pilgrim and Daniel B. Oh of Southwest Sciences, Inc., for **Glenn Research Center**.

Inquiries concerning rights for the commercial use of this invention should be addressed to NASA Glenn Research Center, Commercial Technology Office, Attn: Steve Fedor, Mail Stop 4–8, 21000 Brookpark Road, Cleveland, Ohio 44135. Refer to LEW-17090.



A **Littman-Metcalf Resonator** is used as an external cavity resonator in the wavelength-agile ECDL.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Thermal Imaging for Diagnosing Fuel Cells

A single image reveals a variety of phenomena important to fuel-cell operation.

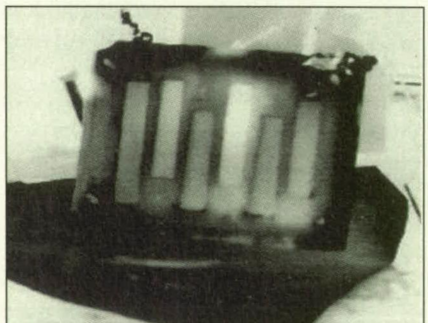
NASA's Jet Propulsion Laboratory, Pasadena, California

Thermal (that is, infrared) imaging has been demonstrated to be an effective technique for the diagnosis of operating fuel cells and fuel-cell stacks. Thermal imaging can be used to identify a variety of phenomena, described below, that are associated with nonuniform generation of heat. Hence, thermal imaging is expected to be widely used in fuel-cell research, development, and manufacturing.

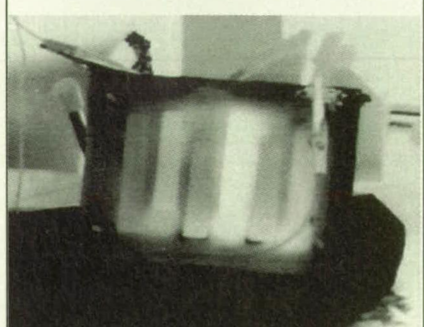
The performances of fuel-cell stacks (especially micro-fuel-cell stacks) are commonly adversely affected by nonuniform distributions of fuel, high resistances of electrical interconnections, cell-to-cell variations, and other phenomena associated with nonuniform generation of heat. The analysis of such phenomena by means of individual cell measurements (e.g., point-probe electric-potential measurements) can be quite tedious, even for a short stack; in the case of flat-pack micro-fuel cells, such measurements are almost impossible. Under these circumstances, one is often left guessing as to the causes of reduced performance.

The generation of heat always accompanies the operation of a fuel cell. The generation of heat is due to inefficiency of the basic fuel-cell electrochemical reaction, crossover (residual diffusion through the fuel-cell solid-electrolyte membrane) of fuel (usually, the fuel is methanol), and electrical heating of interconnection resistances. Temperature differences occur if any of these heat-generating processes occur differently in different parts of a fuel-cell stack. For example:

- Nonuniform distribution of fuel across the surfaces of electrodes leads to nonuniform distribution of electric current and hence temperature differences;
- High-resistance interconnections in a



OPEN CIRCUIT



ELECTRICAL LOAD CONNECTED

These **Infrared Images** of the cathode side of a six-fuel-cell flat pack were recorded under two operating conditions. The nonuniformities of temperature depicted in these images can be analyzed to extract information about processes in the fuel cells and their electrical interconnections.

stack distinguish themselves by producing more heat than the others do; and

- Variations among cells within a stack, arising from variables in fabrication, can cause one or more cells to be more efficient than the others are, leading to thermal gradients.

These examples illustrate how mapping the surface temperature of a fuel-cell stack during operation can yield useful information about the processes occurring in the stack.

Infrared cameras equipped with quantum-well infrared photodetectors (QWIPs) can detect temperature differences as small as 0.005 K. Such a camera has been found to be particularly useful for monitoring processes in fuel cells. For example, the figure shows the temperature variations on the cathode side of a six-fuel-cell flat pack, both in the open-circuit condition and with an electrical load connected. The cell marked 4 exhibits a temperature greater than do the others, even in the open-circuit condition: this is attributed to a high methanol-crossover rate in the particular cell. With the load connected, the interconnections also exhibit differences in temperature, and some of them can be identified to be substantially more resistive than others are.

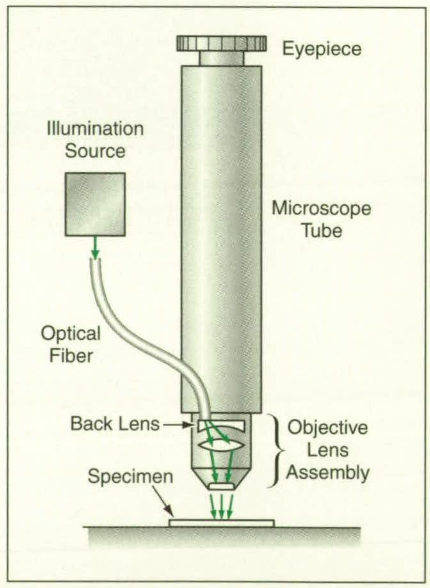
This work was done by Sekharipuram Narayanan and Thomas Valdez of Caltech for **NASA's Jet Propulsion Laboratory**. *For further information, access the Technical Support Package (TSP)* ***free on-line at www.nasatech.com*** *under the Physical Sciences category.*
NPO-21177

Fiber-Optic Illumination for Microscope

Light is injected at the edge of the objective back lens.

NASA's Jet Propulsion Laboratory, Pasadena, California

In a simple but very effective method for providing intense illumination of an opaque specimen under a microscope, light is supplied via an optical fiber. This system eliminates the need for traditional Köhler-type vertical illumination system components, such as beam splitters and lenses, and is easily adaptable to vacuum environments. The output end of the fiber is placed at the edge of the microscope objective back lens (see figure), near the pupil. The light from the fiber passes down through the objective lens, which concentrates the light onto the specimen.



Light Is Supplied from an external lamp via an optical fiber, using the microscope objective lens to focus the light onto the specimen. This simple illumination scheme is relatively inexpensive and, in many cases, more effective than are conventional vertical-illumination schemes that involve complex and bulky optical systems with beam splitters, which waste light.

Tests indicate that alignment of the fiber is not critical since the fiber is not imaged at the specimen. The microscope tube may be a slightly modified commercial off-the-shelf unit, or the fiber may be integrated into the microscope objective lens with a detachable fiber connector so that completely unmodified microscope bodies can be adapted to vertical illumination at low cost. This fiber-optic illumination scheme is expected to be especially useful in microscopy of semiconductor or metallurgical specimens and other opaque objects, as well as in biomedical microscopy.

This work was done by Hiroshi Kadogawa of Caltech for **NASA's Jet Propulsion Laboratory**. *For further information, access the Technical Support Package (TSP)* ***free on-line at www.nasatech.com*** *under the Physical Sciences category.*

This invention is owned by NASA, and a patent application has been filed. Inquiries concerning nonexclusive or exclusive license for its commercial development should be addressed to the Patent Counsel, NASA Management Office–JPL; (818) 354-2240. Refer to NPO-19484.

Enhanced Optical Microresonators for Detecting Molecules

Sensitivity and selectivity would be enhanced by use of fluorophores.

NASA's Jet Propulsion Laboratory, Pasadena, California

Sensors based on microscopic optical resonators and arrays of such resonators have been proposed for detecting trace amounts of specific molecules in small gaseous, liquid, and solid samples. In addition to compactness, these sensors would offer ultrahigh sensitivity — in some cases, enough sensitivity to detect single molecules. These sensors could be especially useful in biochemical and biomedical applications.

The proposed sensors would be enhanced versions of the sensors reported in "Microsphere and Microcavity Optical-Absorption Sensors" (NPO-21061), *NASA Tech Briefs*, Vol. 25, No. 4 (April 2001), page 12a. To recapitulate:

The transducer in a sensor of this type is a fiber-optic-coupled optical resonator in the form of a transparent microspheroid or a microcavity optically equivalent to a microspheroid. Resonance is achieved through grazing-incidence total internal reflection in one or more "whispering-gallery" modes, in which light propagates in equatorial planes near the surface, with integer numbers of wavelengths along closed circumferential trajectories. In the absence of external influences, and assuming that the microspheroid or microcavity is made of a low-loss material, the high degree of confinement of light in whispering-gallery modes results in a high resonance quality factor (high Q).

Suppose that the resonator is illuminated by laser light at its resonance wavelength and is immersed in a sample liquid or gas that has an index of refraction less than that of the resonator material and contains a highly diluted chemical species of interest that absorb light at the resonance wavelength. In that case, the Q of the resonator is diminished through absorption by molecules of that species in the evanescent field of the whispering-gallery modes. Because of the smallness of microresonators (typical diameters from tens to hundreds of optical wavelengths), the smallness of the effective volumes of the evanescent fields (as small as 10^{-10} cm^3), and the low level of optical losses intrinsic to resonators themselves, it is possible to detect very small amounts of optically absorbing chemical species through decreases in Q; calculations have shown that in some cases, it should be possible to detect amounts as small as single atoms or molecules. This completes the recapitulation of information from the cited prior article.

The basic principle of operation as described thus far does not, by itself, afford the sensitivity and selectivity needed to detect a specific chemical species in a quantity as small as a single molecule. What is needed to realize the desired capability is a means of obtaining optical absorption and/or emission at one or more specific wavelengths characteristic of transitions between energy levels of the molecule of interest. Toward this end, the present proposal calls for one or more of the following enhancements:

- The molecules of interest could be marked by use of fluorescent dye molecules that site-specifically bind to them. The microresonator for use in this case would be one that was designed to resonate at a wavelength at which the dye fluoresces. Provided that the microresonator had a Q of at least 10^9 in the absence of the fluorescent dye and the species of interest, it should be possible to detect the absorption of resonator light by a single tagged molecule. The emission of light from the fluorophore could serve, in addition to the absorption-induced decrease in Q, as an amplified indication of the molecular specifics of interest.
- A microresonator would be coated with fluorophores that bind to the molecules of interest. The thickness of the fluorophore coat (typically less than 100 nm) would be small enough that the coat would not significantly alter the Q of the resonator in the absence of the molecules of interest and would be less than the characteristic decay length of the evanescent field. Once a molecule of interest became bound to the coat, the Q of the resonator would change, indicating the presence of the molecule.
- A fluorophore coat like the one described in the preceding paragraph could be applied at an interface between an optical fiber and a microresonator, instead of over the surface of the resonator. In this case, the fluorophore coat by itself would exert little effect on the coupling between the op-

tical fiber and the resonator, but in the presence of a molecule of interest, the optical-transmission characteristic of the sensor would change measurably.

Going a step further, a sensor according to the proposal could be constructed as an array of multiple fiber-optic-coupled microresonators microfabricated on a silicon or other substrate. The microfabrication of the sensor array on the substrate could include etching of channels to support flows of sampled fluids. Each microresonator could be coated with a fluorophore that binds to a different molecule of interest, so that the sensor could detect many molecular species of interest simultaneously.

This work was done by Lutfollah Maleki and Vladimir Iltchenko of Caltech for **NASA's Jet Propulsion Laboratory**. *For further information, access the Technical Support Package (TSP)* ***free on-line at www.nasatech.com*** *under the Physical Sciences category.*

In accordance with Public Law 96-517, the contractor has elected to retain title to this invention. Inquiries concerning rights for its commercial use should be addressed to

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Refer to NPO-21239, volume and number of this NASA Tech Briefs *issue, and the page number.*

System for Measuring Three Tilts and Distance of an Object

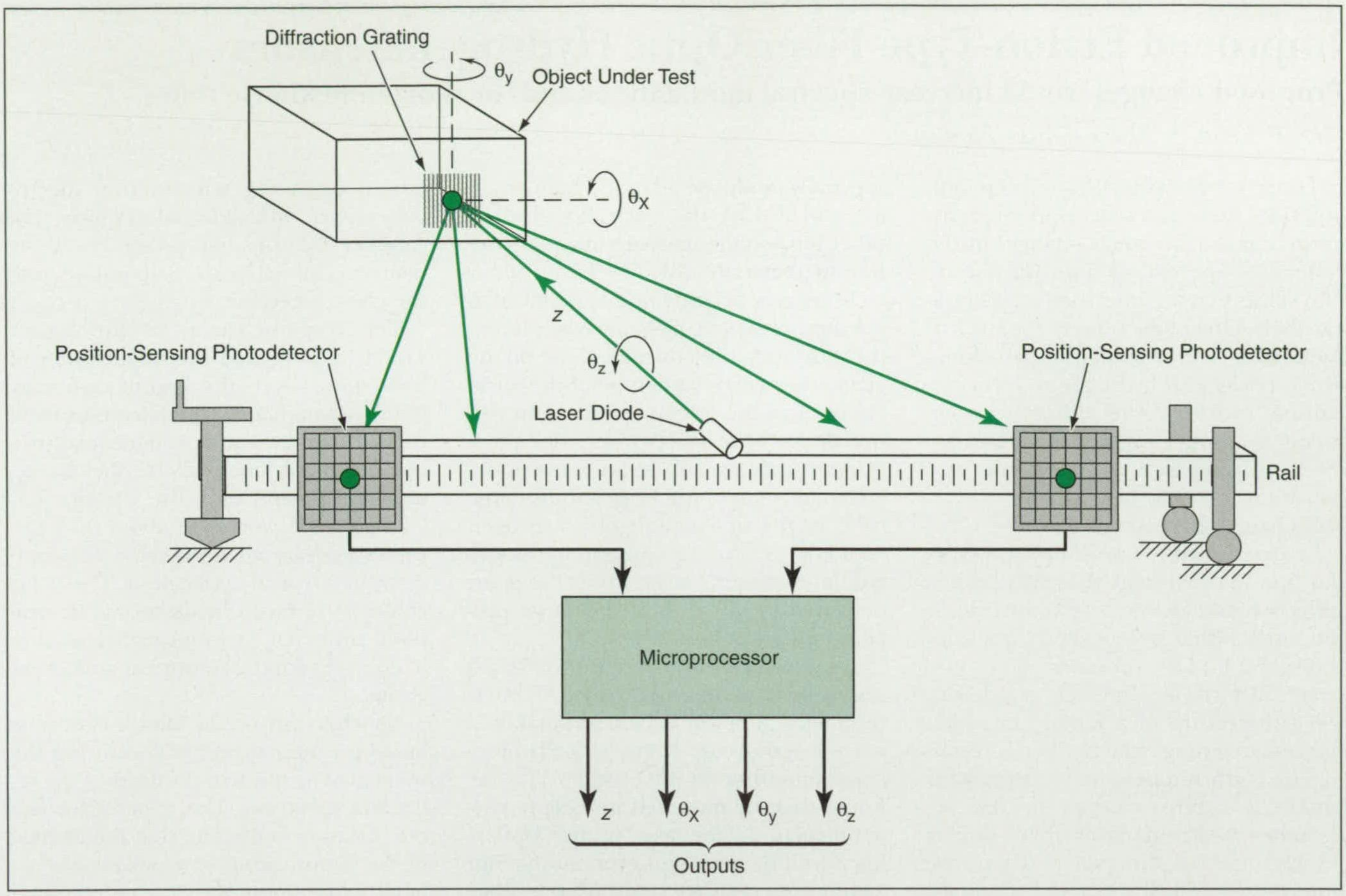
Relative to conventional optical alignment instruments, this system costs less.

NASA's Jet Propulsion Laboratory, Pasadena, California

An optoelectronic system discussed herein measures the state of alignment (SOA) of an object under test in four of its six degrees of freedom (DOFs). This system was originally intended for use in determining the SOA of an optical bench in a vacuum chamber. The basic design and mode of operation of this system are also applicable to similar measurement problems that arise in a variety of endeavors, including general alignment of optics, alignment of structures, studies of deformations of structures, geodetic surveying, photogrammetry, and construction. Heretofore, in order to obtain the alignment information provided by this system, it would have been necessary to use at least two expensive theodolites or else multiple expensive low-distortion camera heads aimed along different lines of sight. The present system contains simpler, less-expensive optics, and its basic design is amenable to tradeoffs among range, sensitivity, and configuration.

The prototype of the system (see figure) includes (1) a reflective diffraction grating mounted on the object under test; (2) a collimated laser diode fixed in a known position and orientation on, and relative to, a dimensionally stable rail; and (3) at least two position-sensing photodetectors mounted at known positions and orientations on the rail. In an alternative version, the laser diode could be affixed to the object under test.

The laser diode is aimed toward the expected location of the reflective diffraction grating on the object under test, thereby generating a fanlike array of diffracted, collimated laser beams. The position-sensing photodetectors are positioned and oriented so that at least one of the diffracted beams would be in-



From the Measured Positions of the Laser Spots on the position-sensing photodiodes, the parameters z, θ_x, θ_y, and θ_z are calculated.

tercepted by each such detector if the object under test were in approximately the expected alignment. The outputs of the detectors are digitized, processed by image-data-processing software, and further processed by software that implements the geometric relationships among (1) the locations of the centroids of the laser-beam spots on the detectors, (2) the laser wavelength, (3) the spatial period of the grating, (4) the distance between detectors, (5) the diffraction order, and (6) the position and orientation of the diffraction grating (and thus of the object under test). The final data product is a set of parameters that specify the position and orientation of the object in four degrees of freedom: range (distance along the laser beam between the laser diode and the center of the grating), the angle of rotation (θ_z) of the grating about the laser-beam axis, and the angles of rotation (θ_x and θ_y) of the grating about two coordinate axes perpendicular to the beam axis.

This work was done by Eric B. Hochberg of Caltech for **NASA's Jet Propulsion Laboratory**. *For further information, access the Technical Support Package (TSP)* ***free on-line at www.nasatech.com*** *under the Physical Sciences category.*
NPO-21086

Improved Etalon-Type Fiber-Optic Hydrogen Sensors

Proposed changes would increase spectral modulations and/or shorten response times.

John F. Kennedy Space Center, Florida

Three modifications have been proposed for hydrogen sensors in which hydrogen in the air causes changes in the reflection spectra of interferometric film stacks that are interrogated via optical fibers. One of the films in the stack in each such sensor contains palladium, which reacts with hydrogen to form palladium hydride. The differences between the optical absorbances and indices of refraction of palladium and palladium hydride give rise to observable changes in spectra.

In an unmodified sensor of this type, the film that contains the palladium is reflective and is the outermost film in the stack, which is deposited on a thin, transparent glass substrate. The substrate, in turn, is adhesively bonded to the polished tip of a ferrule in which the interrogating optical fiber is terminated. Unfortunately, it is difficult to obtain a robust change in the reflectance spectrum of this or any similar interferometric film stack when the outermost film is the one that changes. In this case, the differences between the indices of refraction and optical absorbances of palladium and palladium hydride in the outermost layer are not large enough to elicit the desired robust change.

The situation would be different if the film containing the palladium were the innermost layer in the stack (the layer closest to the interrogating optical fiber), because in such a case, the film would spectrally modulate all of the light entering and leaving the stack. Because the other films in the stack are made of nonporous materials with low permeability by hydrogen, it would not be practical to attempt to exploit this effect by placing the film containing the palladium on the glass substrate at the bottom of the stack. However, if the stack from the unmodified design were simply inverted and positioned with a small airgap between the palladium-containing layer and the optical fiber, the air containing the hydrogen could diffuse through the gap to the palladium-containing layer: this is the point of departure for one of the three proposed modifications.

Figure 1 illustrates a reflection-based sensor head as thus modified. The interferometric film would be deposited on a narrow sensor bar with the palladium-containing film on the outside. The bar would then be mounted in a plane perpendicular to the axis of the optical fiber, with the palladium-containing film facing the polished end of the fiber across an airgap about 0.1 mm wide. The gap would be maintained by use of a glass or ceramic ring bonded adhesively to the tip of a capillary tube, which would serve as a pedestal and as a ferrule to hold the optical fiber. A thin-film electrical heater could be deposited on the sensor bar along with the interferometric films to obtain intimate thermal contact and thus highly energy-efficient heating of the films to maintain the required operating temperature. Electrical contact with external circuitry that supplies the heating power could be made via metal pads evaporated onto the glass or ceramic ring.

The response delay of the sensor would be governed by the diffusion of hydrogen. Given the known diffusivity of hydrogen in air, it has been estimated that at standard atmospheric pressure and a temperature of 20 °C, the characteristic diffusion time for a sensor bar 0.2 mm wide would be about 0.11 ms; this would be an acceptable response delay in a typical application. The delay could be reduced by use of an air-sampling unit that provides sufficient flow in contact with the sensor bar and its environs.

Another proposed modification is based on the concept of measuring the transmission spectrum instead of the reflection spectrum. The impetus for this modification is the fact that the change in the transmission of a palladium-containing film upon exposure to hydrogen exceeds the change in its reflection; consequently, at a given hydrogen concentration, the output of a transmission-based sensor should exceed that of the reflection-based sensor described above.

Figure 2 shows two alternative configurations for the proposed transmission-based sensor. In the first configuration, light from a small source would be collimated by a lens. The light would pass through the etalon, then through an-

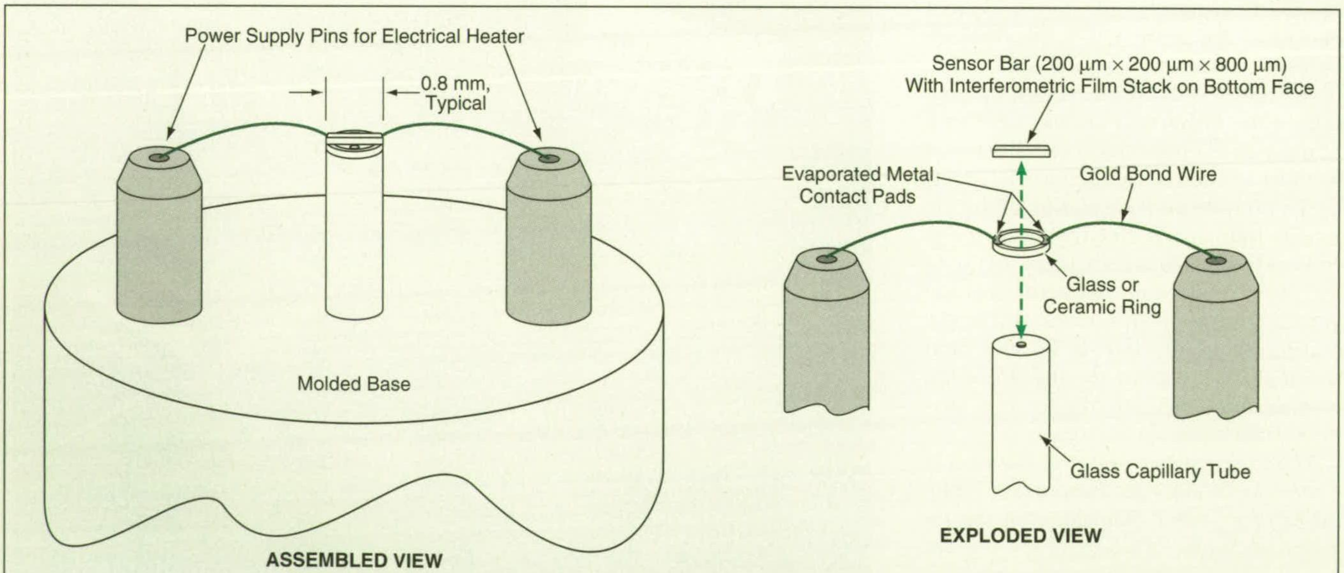


Figure 1. The **Interferometric Film Stack** on the bottom of the sensor bar would exhibit a reflectance spectrum that would depend on the hydrogen content of the air in contact with a palladium-containing layer facing the optical fiber. The stack would be interrogated via the optical fiber.

other lens that would focus the light onto a photodetector. Hydrogen would diffuse to the etalon through a small airgap between the etalon and the focusing GRIN lens.

The source of light could be two light-emitting diodes (LEDs) of different colors mounted in proximity on the same header. One LED would be chosen to have a wavelength (about 450 nm) in the vicinity of maximum change in transmission upon exposure to hydrogen. The other LED would be chosen to have a wavelength (typically in the infrared) for which there is little change in optical properties on exposure to hydrogen; the signal from this LED would serve as an amplitude reference.

Alternatively, the source of light could comprise multiple LEDs that would be turned on and off in sequence to obtain the transmission responses at the various LED wavelengths. Yet another alternative would be to illuminate the etalon with white light, in which case it would be necessary to analyze the transmitted light by use of a spectrometer. A suitable spectrometer could be constructed from a diffraction grating and a linear array of photodiodes. This alternative would provide more information than would the two-LED design described above, albeit at increased complexity and cost.

Although lenses shown in the figure are of the gradient-index-of-refraction (GRIN) type, other types could be used. The advantage of GRIN lenses in this application is that their ends can be made flat; this makes it possible to fabricate the etalon directly on the end of the collimating lens, reducing the size and complexity of the sensor.

The second configuration would involve the same principle of operation, but light would be coupled into and out of the sensor by different means. In this configuration, light would be delivered to the etalon from a remote source via a first optical fiber, and light transmitted through the etalon would be delivered to the photodetector(s) or spectrometer via a second optical fiber. In this case, the etalon could be fabricated on the polished output end of the first optical fiber, and the airgap would lie between the etalon and the input end of the second optical fiber. (Alternatively, the etalon could be fabricated on the end of the second optical fiber.) The core of the second fiber would be made wider than the core of the first fiber so that the second fiber could capture all of the transmitted light, without need for a collimating and a focusing lens.

The use of optical fibers would make it possible to mount the sensor away

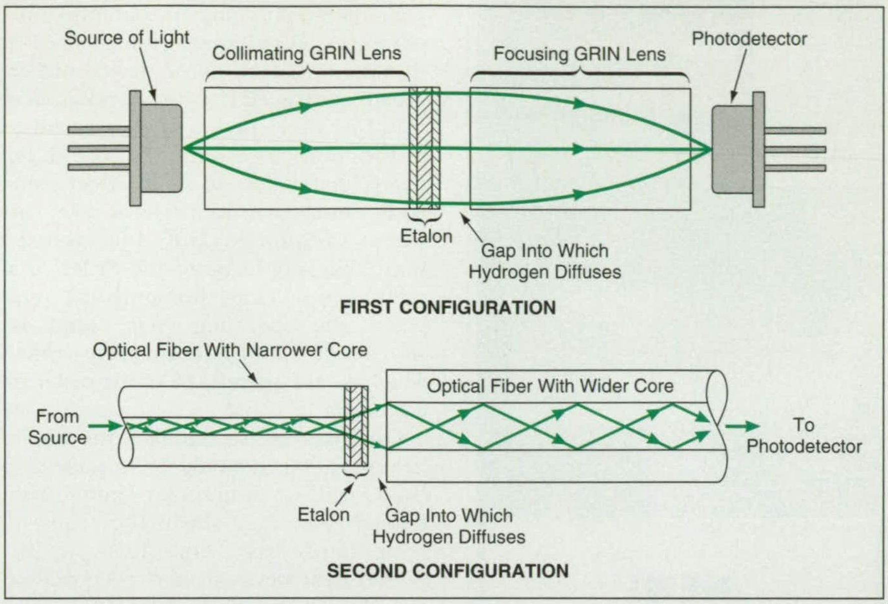


Figure 2. **Light Would Be Transmitted** through an etalon, the transmission spectrum of which would be altered by hydrogen in the air.

from the associated electronic circuitry. This could be advantageous in situations in which the circuitry would be vulnerable to electromagnetic interference or to damage if it were placed at the sensor location.

The third modification would be the introduction of pulsed optical heating to decrease response times. This modification would exploit the observations that (1) the response time in desorption of hydrogen is typically about 12 times that in absorption, (2) the response time decreases with temperature, and (3) optical modulation goes to zero as the temperature is increased to 80 °C, suggesting that all of the hydrogen becomes desorbed from the

palladium-containing film at this temperature. These observations suggest that the overall response time could be greatly shortened if the desorption time could be shortened, and, in particular, if the film containing Pd could be heated quickly to 80 °C to effect complete desorption. In a typical case, the thermal-response (and thus desorption) time would be of the order of a millisecond. Thus, for practical purposes, the operating cycle could be shortened to the absorption time, which would typically be of the order of a minute.

One way to accomplish the rapid heating to 80 °C would be to pulse the interrogating source of light with enough power to obtain the required temperature rise. Optionally, if the pulsed light were infrared, then one of the films in the etalon (not necessarily the one containing Pd) could be made of InSb to enhance absorption of infrared. In the case of a transmission-based etalon sensor, the fraction of light transmitted would change during each illuminating pulse; specifically, the film containing Pd would become less transparent as the hydrogen was desorbed. Thus, the hydrogen content of the air could be inferred from the decrease, during each pulse, in the fraction of light transmitted. As an important side benefit of this approach, there would be no need to provide additional means to generate a reference or baseline signal because the optical signal would be returned to its baseline level as the hydrogen was expelled with each pulse.

This work was done by Elric W. Saaski and Charles Young of Research International, Inc., for **Kennedy Space Center**. *KSC-11981*

Algorithm for Optimizing Designs of Diffractive Optics

Diffractive optical elements with continuous phase profiles can be designed rapidly.

Marshall Space Flight Center, Alabama

An algorithm for optimizing the designs of diffractive optics is based on constrained dynamics and the reciprocity of electromagnetic propagation. This algorithm can contribute to realization of the potential of diffractive optics, which offer capabilities greater than those of refractive optics. Because the diffractive-optics design-optimization problem is equivalent to determining the diffractive limit of phase-only propagation compensation by adaptive optics, the algorithm could be used to create control algorithms for adaptive optics. In addition, the mathematical techniques and physical principles used in developing the algorithm could be used in solving the problem of phase retrieval for characterizing wavefronts.

The design and optimization of diffractive optics are generally more complex and computationally intensive than are the design and optimization of refractive optics. Prior to the development of the present algorithm, most of algorithms used for the same purpose were based on propagation only in the forward direction; that is, from the diffractive optical element(s) to the diffraction plane. In each such prior algorithm, an initial guess (often a random configuration) of the design of the diffractive optical element(s) is made, and stochastic integration techniques are used to improve the initial guess by generating more random configurations and then deciding which ones are better and headed in the direction of the desired optimized design. Such algorithms are computationally inefficient (and hence time-consuming) because they must generate many tentative design configurations, most of which must be discarded because they are far removed from design specifications.

The computational burden associated with generating many random configurations makes it impractical to produce designs with more than a limited number of degrees of freedom per phase-template pixel; that is, phase templates generated by such algorithms can contain only a few quantized levels or steps in phase. However, it is possible to manufacture diffractive optical elements with continuous phase profiles.

Hence, what is needed to realize the potential of diffractive optics is a computationally efficient algorithm that generates phase templates with continuous phase profiles. The present algorithm satisfies this need. Because random configurations are not used and physical

quantities are treated as continuous in the first place, there are no restrictions on the number of degrees of freedom per phase-template pixel.

Mathematically, reciprocity of electromagnetic propagation is a consequence of the symmetry of Maxwell's equations. The present algorithm takes advantage of the reciprocity of electromagnetic propagation to propagate design information both from the diffractive optical elements forward to the diffraction plane and from the diffraction plane backward to the diffractive optical element(s). In so doing, the algorithm utilizes maximally the information available on both the diffractive-element and diffraction planes. Moreover, because the algorithm is ultimately based on Maxwell's equations, it can, in principle, be applied to a wide variety of diffractive optical elements, including those for which vector diffraction analysis is necessary.

The constrained-dynamics aspect of the algorithm makes it possible to solve the design-optimization problem through successive approximation. Each iteration brings the design solution closer to the optimized design solution, and no randomness is involved.

This work was done by S. Enguehard and B. Hatfield of Applied Mathematical Physics Research, Inc., for **Marshall Space Flight Center**. *For further information, contact the company at (781) 862-6357, or access the Technical Support Package (TSP)* ***free on-line at www.nasatech.com*** *under the Physical Sciences category.*

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Refer to MFS-31427, volume and number of this NASA Tech Briefs *issue, and the page number.*

Computer Program for Designing Diffractive Optics

This program fills a gap left by available refractive-optics-design software.

Marshall Space Flight Center, Alabama

AMPERES is a prototype computer program that implements the algorithm, described in the preceding article, for optimizing designs of diffractive optics. Several other programs for designing refractive optics are commercially available, but they offer very limited capabilities with respect to diffractive optics. AMPERES was developed to fill this gap and to serve as an easy-to-use means for designing diffractive optics.

Unlike programs for designing refractive optics, AMPERES is based completely on wave optics (as distinguished from ray optics). The optimization-engine part of AMPERES is founded on reciprocity of electromagnetic propagation, utilizing a conceptual framework of constrained Lagrangian dynamics.

AMPERES produces designs for kinoform phase templates for fan-out gratings, radial phase elements, two-dimensional holograms, and refractive correctors for single thick lenses. A unique aspect of the refractive-correction module of AMPERES is that this module even treats thick refractive lenses in the wave-optics regime.

AMPERES generates phase templates with 128×128-pixel resolution. The template phase-profile designs can be either continuous or quantized (binary) with 2, 4, 6, 8, or 16 levels. Diffraction-plane images are produced for all designs. AMPERES is completely menu-driven. The interface for design input is graphical. Any stored results can be redisplayed by use of a viewer software module.

Computation by AMPERES is rapid, efficient, and accurate. The program can be executed on a common desktop personal computer.

This work was done by S. Enguehard and B. Hatfield of Applied Mathematical Physics Research, Inc., for **Marshall Space Flight Center**. *For further information, contact the company at (781) 862-6357 or access the Technical Support Package (TSP)* ***free on-line at www.nasatech.com*** *under the Physical Sciences category.*

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Ring-Resonator/Bragg-Grating Laser-Feedback Elements

Semiconductor-laser spectral lines would be rendered narrow enough for metrology.

NASA's Jet Propulsion Laboratory, Pasadena, California

Integrated optical structures that contain ring resonators and Bragg gratings have been proposed as external feedback elements for semiconductor lasers. These feedback elements would constrain the laser spectra to narrow lines (more precisely, narrow spectral bands) centered at desired wavelengths. In the original intended applications, these feedback elements and the associated lasers would be constructed and operated in pairs to generate pairs of spectral lines separated by known wavelength intervals in the approximate range of 1 to 10 nm, as needed to resolve integer-multiple-of-wavelength ambiguities in laser metrology.

A ring resonator according to the proposal (see figure) would include a ring optical waveguide comprising a core of SiON (index of refraction = 1.483) and a cladding of SiO_2 (index of refraction = 1.463), formed on a substrate of Si by use of plasma-enhanced chemical vapor deposition. The resonator would also include two straight waveguides — one for input and one for output. The straight waveguides would be laid out in proximity to the ring waveguide, so that light would be coupled between the straight and ring waveguides via the evanescent-wave interaction. The overall operation of the resonator, in terms of transmissivity between ports 1 and 2 as a function of wavelength, would be similar to that of a Fabry-Perot etalon: the transmissivity spectrum would contain multiple sharp resonance peaks reminiscent of a comb.

A Bragg grating would be incorporated into one of the straight waveguides to select one of the ring resonances. To be effective for this purpose, the Bragg grating must be designed and fabricated to have a reflectance peak narrower than twice the free spectral range of the resonator — that is,

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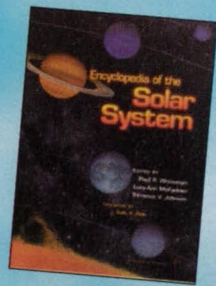

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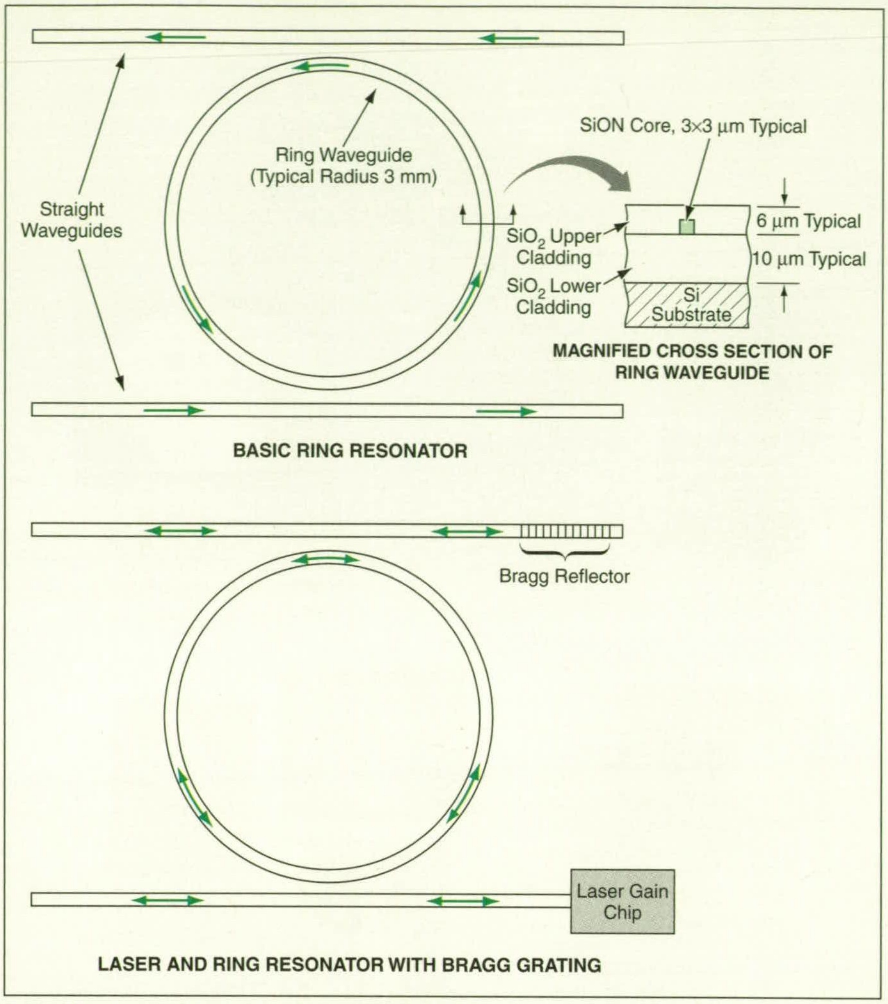

A **Ring Resonator and Bragg Reflector**, combined into an integrated optical feedback structure, is expected to enable a semiconductor laser to generate a spectrum much narrower than it otherwise would.

narrower than double the spectral interval between successive resonance peaks. It would also be necessary to match the transmission pass band of the grating with one of the resonance peaks. An electric-heater element could be deposited on the ring or on the grating for this purpose: selective heating of the ring or grating could vary the resonance peaks or the pass band to effect this match.

For an example involving a wavelength of 1.55 µm, ring radius of 3 mm, and propagation loss of 0.2 dB/cm, the resonance quality factor (Q) was estimated to be 10^5. Assuming further that the requirements stated in the preceding paragraph were satisfied, that the reflectivity of the Bragg-grating in the vicinity of one of the ring resonances was about 0.97, and that the interface reflectivity was 3 percent, it was estimated that laser gain chip that would ordinarily emit a spectral line 50 MHz wide when operated by itself would emit a spectral line with a width of 10 kHz or less when operated with this feedback structure connected to it. A width of 10 kHz is comparable to the spectral widths of neodymium-doped yttrium aluminum garnet (Nd:YAG) lasers used heretofore in metrology.

This work was done by Alexander Ksendzov of Caltech for **NASA's Jet Propulsion Laboratory**. *For further information, access the Technical Support Package (TSP)* ***free on-line at www.nasatech.com*** *under the Physical Sciences category.*

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Laser Sensor for Edge Detection

Automatic Timing and Controls, Lancaster, PA, introduces the Model 7703AR04N3BQP laser sensor, a compact Class 2 device in a rugged housing. It offers both proximity and reflective mode sensing. Light Operate and Dark Operate are user selectable, with an adjustable power potentiometer. The sensor can be connected for either NPN or PNP output, and operates from 10 to 30 VDC. The unit's spot size is less than 1 mm at 2 feet, with little divergence over distances up to 160 feet, according to the company.

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Workstations for Vibration Isolation

The family of vibration isolation products from Kinetic Systems, Boston, MA, includes a line of workstations for personal, midrange, and heavy-load configurations. The company says all designs provide a vibration-controlled work environment with low natural frequencies and high vertical and horizontal isolation efficiencies. The Personal Workstations are designed for small labs and tight spaces, and will accommodate loads up to 440 lbs. The larger midrange designs can control loads up to 1300 lbs., and the heavy-load models 2800 lbs.

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Nd:YAG DPSS Laser

Cutting Edge Optronics, St. Charles, MO, has introduced the Scimitar™ laser, a 1064-nm Nd:YAG diode-pumped solid-state instrument that can produce 150 W multimode or 20 W TEM_{00}. The Scimitar is equipped for continuous-wave or acousto-optic Q-switch operation from 1 to 50 kHz, and it also has a green output option, producing up to 35 W at the 532-nm wavelength. The company says that applications for the Scimitar include micromachining, welding, cutting, ablating, drilling, fast laser marking, engraving and sintering.

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Telecentric Lenses for Machine Vision

LINOS Photonics, Milford, MA, is offering a standard line of telecentric lenses for industrial machine vision applications. The company says the lenses are insensitive to small variations of the object distance, have high resolution and low distortion, and are of a robust mechanical design. They are designed for an object distance of 250 mm (9.75 in.) and for 2/3-in., 1/2-in., and 1/3-in. CCD camera formats, and optimized for maximum object diagonals of 25 mm and 50 mm. For wavelength matching, the lenses have a standard M 67 × 0.75 filter threads.

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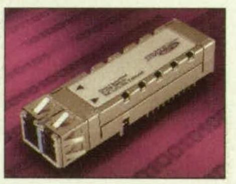

SONET-Compliant Optical Transceiver

Stratos Lightwave, Chicago, IL, makes available a family of SONET-compliant small-form-factor (SFF) optical transceivers. Versions for OC-48 (2.488 Gb/s), OC-12 (622 Mb/s), or OC-3 (155 Mb/s) are available. Featuring a 2- by 10-pin configuration, the high-density transceivers are designed for the next generation of metropolitan area networking and telecommunications, according to Stratos. They feature TTL signal detect output and transmitter disable input. The devices operate at 1310 nm with single-mode cable and industry-standard FC connectors.

For Free Info Circle No. 735 or Enter No. 735 at www.nasatech.com/rs

Laser Sensor for Glass Thickness Measurement

LMI Selcom, Detroit, MI, is offering a Class II visible laser sensor and controller capable of measuring flat glass thickness and profile at a speed of 2000 readings per second. The Glass Thickness Sensor (GTS) sends a laser beam onto the glass at an angle of 49 degrees from perpendicular. The laser light appears on both sides of the glass being measured and reflects back into a sensor/detector. The GTS measures glass thickness from 0.3 mm to 4 mm at a standoff distance of 26-30 mm. LMI Selcom suggests applications would include LCD glass, medical glass, digital video disks, and fluorescent chips.

For Free Info Circle No. 736 or Enter No. 736 at www.nasatech.com/rs

Carbon Dioxide Laser Lenses

Laser Research Optics, Providence, RI, offers a broad range of carbon dioxide laser lenses and windows for use in industrial and medical lasers. The lenses are available from 0.6 in. to 2.0 in diameters, and focal lengths from 1 in. to 20 in. in 0.1-in. increments, depending upon configuration, and in sizes up to 3.0 in. in diameter for use as windows. Suitable for laser systems from 25 to 200 W, the zinc selenide positive-focusing lenses provide less than 0.25 percent total absorption values.

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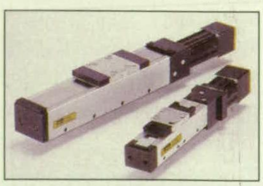


Miniature Positioners

The new 401XR and 402XR miniature positioning tables from Parker Hannifin's Daedal Division, Irwin, PA, are only 1.6 in. and 2.3 in. wide. Standard features are protective strip seals, precision-ground ballscrew, and high-strength recirculating bearing system. Modular options include noncontact linear encoders with resolutions to 0.1 micron and several connectorized limit and home sensors. The XR tables are configured with selectable motor block and couplings to accept any industry-standard servo or step motor.

For Free Info Circle No. 738 or Enter No. 738 at www.nasatech.com/rs

Video Scan Converter

RGB Spectrum, Alameda, CA, adds the Model 1690 to its RGB/Videolink® family of video scan converters. It accepts interlaced or noninterlaced RGB inputs from virtually any workstation or desktop computer. The unit synchronizes to all computer signals with screen resolutions up to 1600 × 1280 pixels and with scan rates from15 kHz to 90 kHz. As outputs, the device offers NTSC/PAL composite video, S-Video, and component analog video. Digital signal processing circuitry is used to eliminate interlace flicker in the output image. SMPTE 259M digital output is available as an option.

For Free Info Circle No. 739 or Enter No. 739 at www.nasatech.com/rs

Broadband Infrared Spectral Radiometer

Electro-Optical Industries, Santa Barbara, CA, introduces the Model RSA2000-CVF infrared spectral radiometer. The company says the unit was designed with optics with diameters of 8 in. to enhance sensitivity, and a circularly variable filter for high-resolution spectral analysis. The cryoengine-cooled dual detector enables wide spectral response of 1.4 to 14 microns with less than 1 percent lambda spectral resolution. The color-corrected Cassegrain telescope has four fields of view: 2.5 mrad, and 2, 5, and 10 degrees.

For Free Info Circle No. 740 or Enter No. 740 at www.nasatech.com/rs

Relatively Simple Atmospheric-CO_2 Controller

Temperature of an alkanolamine solution is controlled to make it absorb or desorb CO_2.

Lyndon B. Johnson Space Center, Houston, Texas

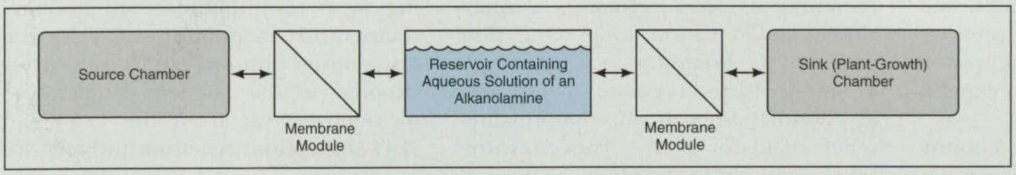
An apparatus has been developed as a means of controlling the partial pressure of CO_2 (pCO_2) in air in a closed or semi-closed environmental system. The apparatus takes CO_2 from the air in a source chamber and supplies the CO_2, at a regulated partial pressure, to the air in a sink chamber. In the original intended application, the chambers would be located aboard a spacecraft: the source chamber would be inhabited by crewmembers, and the sink chamber would be a plant-growth chamber. Apparatuses like this one could also be used to control pCO_2 in research plant-growth chambers on Earth.

In comparison with prior pCO_2-regulating apparatuses built around sources of compressed gases, mass-flow controllers, CO_2 sensors, and/or single-use sorbents, this apparatus consumes less expendable material and is relatively simple and inexpensive. In this apparatus (see figure), CO_2 is gathered from the source atmosphere, across a semipermeable membrane, into a reservoir that contains an aqueous solution of an alkanolamine. Depending on conditions, such a solution absorbs or desorbs CO_2; the CO_2 load in the solution depends on the pCO_2, duration of exposure, and temperature. From the solution, CO_2 is transferred, as needed, across another semipermeable membrane, to the atmosphere in the sink chamber. Because the release of CO_2 to the atmosphere in the sink chamber is an equilibrium process, the resulting pCO_2 in the sink chamber depends on both the CO_2 loading of the alkanolamine and the temperature and can be controlled, within specified limits, by changing the temperature of the alkanolamine solution.

In the case of an inhabited source chamber, the pCO_2 in that chamber can generally be expected to exceed the pCO_2 required for a sink chamber in which plants are to be grown. In such a case, CO_2 can be gathered periodically from the source chamber to maintain the required CO_2 loading of the solution while the required pCO_2 in the plant-growth chamber is maintained through equilibrium exchange. Because of the large CO_2 capacity of the alkanolamine, stable control of the pCO_2 in the plant-growth chamber is easily achieved.

When the pCO_2 in the source chamber is less than the pCO_2 required in the sink chamber, temperature-dependent solubility is used to pump CO_2 against its concentration gradient: Inasmuch as the equilibrium pCO_2 above the alkanolamine solution increases with temperature, CO_2 is gathered through the membrane on the source-chamber side at a temperature lower than that at which it is released through the other membrane on the plant-growth-chamber side.

The absorption of CO_2 in an alkanolamine solution takes place through reversible ionization reactions that change the relative abundance of electrically conductive species in the solution. As a result, there is a relationship between the electrical conductance of the solution and its CO_2 load. This relationship is exploited in the present apparatus: The electrical conductance measured at a given temperature is taken as an indication of the CO_2 loading of the solution and, by extension, of the equilibrium pCO_2 of the atmosphere in contact with the solution.



The **Alkanolamine Solution in the Reservoir** acts as a buffer for CO_2: Its temperature is varied to make it store or release CO_2 as needed to maintain a required pCO_2.

This work was done by Jeffrey L. DeHart, James R. Akse, and James E. Atwater of Umpqua Research Co. for **Johnson Space Center.** *For more information, contact the Johnson Commercial Technology Office at (281) 483-3809.*
MSC-22911

A Technique for Injecting Ag^+ Ions as Biocide into H_2O

Lyndon B. Johnson Space Center, Houston, Texas

A simple and reliable technique facilitates the addition of silver ions to water supplies to suppress bacterial contamination. In the original application for which the technique was devised, there is a need for Ag^+-ion concentrations at a biocidal levels (0.5 mg/L) in 44-L batches of drinking water. The technique involves the preparation of a solution of concentrated biocide by dissolving 0.66 g of AgF and 1.04 g of NaF in 0.5 L deionized water. Batches of the solution are put into plastic syringes that have volumes of 20 cm^3 each and are equipped with fittings for connection to the water supplies to be treated. The syringes are capped and placed in plastic bags for transport and storage. The shelf life of the syringes stored at room temperature is at least two years. When needed, a syringe is simply unpacked and connected to a mating fitting on a water supply. The concentrated solution is then injected into the flowing water, wherein the solution becomes diluted to the desired final concentration.

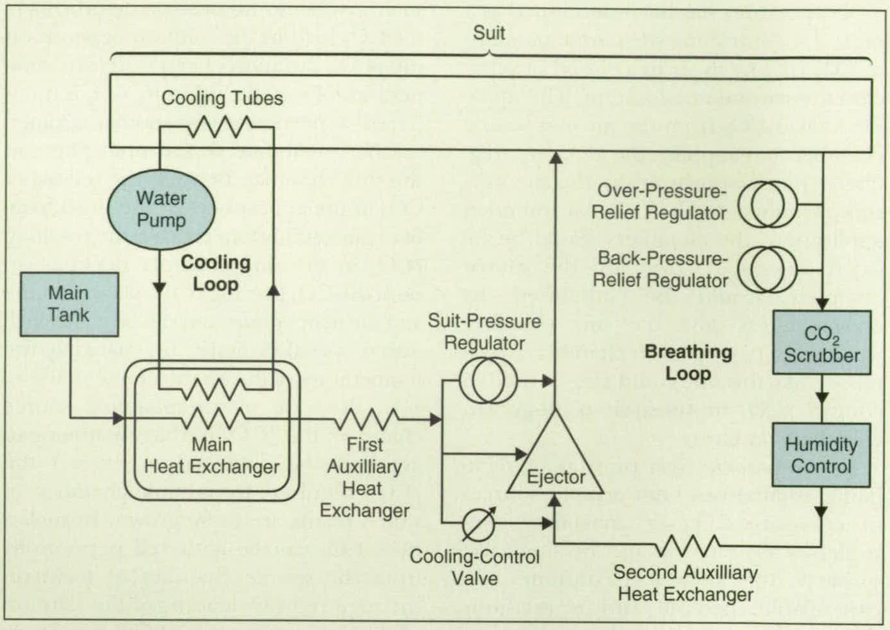
This work was done by Richard L. Sauer of **Johnson Space Center** *and Paul D. Mudgett and John R. Schultz of Wyle Laboratories. For further information, access the Technical Support Package (TSP)* ***free on-line at www.nasatech.com*** *under the Materials category.*
MSC-23170

Breathing-Air and Cooling Apparatus for Protective Suit

Applications can include diving, space, and firefighting suits.

Lyndon B. Johnson Space Center, Houston, Texas

The figure schematically illustrates a portable life-support apparatus for any of a variety of protective suits to be worn in hostile environments. A prototype of the apparatus has been fitted to space suits for use underwater. Astronauts wear these suits during training dives in a tank of warm water, using the neutral buoyancy available in the underwater environment to simulate aspects of the zero gravitation of outer space. The apparatus provides breathing air and adjustable cooling in the suit, while maintaining overall neutral buoyancy. The apparatus is readily adaptable to such related applications as conventional diving and space suits, firefighting suits, and protective garments to be worn in hot, toxic, and/or radioactive environments.



The **Cooling and Breathing Loops** are both energized by the flow of liquid air expelled from the main tank by pressurized gas.

The apparatus is shown schematically in the figure. The source of both breathing air and cooling is a supply of liquid air inside part of the volume of an insulated tank. The part of the tank that contains the liquid air is separated from the rest of the tank by an insulated piston. The rest of the tank is pressurized, by use of a small cylinder of compressed gas, to a level greater than the pressure in the liquid air, so that the piston pushes against the liquid air to expel it from the tank as needed.

The apparatus includes a cooling loop, in which a pump circulates water between a main heat exchanger and cooling tubes in the protective suit. When liquid air flows from the tank, it passes through the heat exchanger, where it absorbs heat from the circulating water. Thus, in a single action, the main heat exchanger both removes the wearer's body heat from the circulating cooling water and uses this heat to help vaporize the liquid air and warm it to a breathable temperature. At the outlet of the main heat exchanger, the flowing air may be too cold to breathe, and some of it may still be in liquid form. Accordingly, the flow is then made to pass through a first auxiliary heat exchanger, where any remaining liquid fraction is vaporized and warmed to a breathable temperature.

From the outlet of the first auxiliary heat exchanger, the air flows via one or more of three paths into the breathing-air loop, which is a semi-closed air-circulation loop. One flow path into the breathing loop is through a suit-pressure regulator that acts in conjunction with an over-pressure-relief regulator and a back-pressure-relief regulator to maintain the desired pressure (to simulate suit pressure in a vacuum) in the suit. Another path is directly into an ejector, wherein the flow is formed into a high-speed jet, the momentum of which is then transferred to the immediately surrounding air to obtain a pumping action to circulate the air in the breathing loop without need for a blower with moving parts. The third path is through a cooling-control valve, which the wearer adjusts manually to adjust the overall rate of flow of air out of the main tank and thereby adjust the rate of cooling.

Within the breathing loop, the exhaled carbon dioxide is removed from the circulating air by use of a CO_2 scrubber. Exhaled and other excess moisture is removed by a humidity-control unit, which is simply a bed of desiccant material. The breathing loop also includes an auxiliary temperature regulator, wherein the circulating atmosphere is selectively exposed to the ambient temperature to remove heat from the CO_2- and H_2O-absorption reactions, which are exothermic.

This work was done by Bruce Caldwell of Oceaneering Space Systems for **Johnson Space Center.** *For further information, access the Technical Support Package (TSP)* ***free on-line at www.nasatech.com*** *under the Machinery/Automation category.*

Title to this invention, covered by U.S. Patent No. 5,365,745 has been waived under the provisions of the National Aeronautics and Space Act {42 U.S.C. 2457 (f)}. Inquiries concerning licenses for its commercial development should be addressed to

John C. Propeck
Oceaneering Space Systems
16665 Space Center Blvd.
Houston, TX 77058

Refer to MSC-22442, volume and number of this NASA Tech Briefs *issue, and the page number.*

Thermoelectric Contact Cooler/Freezer

This cooler is efficient and quiet.

Lyndon B. Johnson Space Center, Houston, Texas

A thermoelectric contact cooler/freezer is designed to utilize thermal conduction to rapidly freeze blood and urine samples in test tubes and syringes. This apparatus is dependable, wastes little energy, contains no moving parts other than a fan, can operate in a wide temperature range and in any orientation (including in zero gravity), is quiet, and emits no chlorofluorocarbons or other greenhouse gases. It is a vast improvement over currently available convection-type cooler/freezers.

Convection-type cooler/freezers do not freeze samples as rapidly as do conduction freezers; this is a major consideration because if samples are frozen too slowly, then their integrity is threatened. Convection-type cooler/freezers are unreliable because they are best on the use of chlorofluorocarbon fluids and compressors; leaks can occur, contributing to the greenhouse effect, and the compressors are very noisy during operation. In addition, convection-type cooler/freezers are less efficient.

The thermoelectric contact cooler/freezer includes an aluminum two-part housing, a pair of cold plates, thermoelectric elements, a fan, and a temperature-control unit. The cold plates contain machined semicircular-cross-section grooves that constitute receptacles into which test tubes or syringes can be inserted. The plates are spring-loaded against each other to provide gentle clamping of, and thus thermal contact with, the tubes or syringes in the grooves. The thermoelectric elements are mounted on the cold plates and are attached to free-floating, finned, hot-side heat sinks.

The apparatus is powered by direct current, which causes the thermoelectric elements to transfer heat from the cold plates to the heat sinks. When this happens, the fan blows air over the heat-sink fins to dissipate the heat from the heat sink.

One of the attributes that makes this cooler/freezer attractive from an industrial perspective is that it can be produced in various sizes. Small, lightweight portable units are now available. Thermoelectric contact cooler/freezers like this one have been proposed to be included as subassemblies of larger cooling/storage units required to perform quick freezing in outer space. Because of its energy efficiency, dependability, quietness, and environmental suitability, the thermoelectric contact cooler/freezer could prove useful in any setting in which rapid freezing is needed to maintain the integrity of samples — particularly in laboratories, hospitals, and clinics, as well as in the spacecraft environment for which it was developed.

This work was done by James D. Moncrief of **Johnson Space Center** *and Danny D. Demonbrun of G. B. Tech. For further information, access the Technical Support Package (TSP)* ***free on-line at www.nasatech.com*** *under the Machinery/Automation category.*
MSC-22631

Molten-Carbonate Electrolyzers for Making CO and O_2

Molten-carbonate fuel cells would be operated in reverse.

NASA's Jet Propulsion Laboratory, Pasadena, California

Electrochemical cells in which molten carbonates would serve as electrolytes have been proposed for use in electrolyzing CO_2. The proposal was made in an effort to implement a concept of *in situ* resource utilization (ISRU) for the exploration of Mars; the basic idea is to generate CO (if needed as a fuel) and O_2 (for oxidizing fuel and/or for breathing) by electrolysis of CO_2 from the Martian atmosphere. On Earth, molten-carbonate electrolyzers could be used to make breathable O_2 for medical use, pure O_2 for oxidizing surfaces of semiconductor chips, and CO as a feedstock for synthesis of alcohols and hydrocarbons. In both terrestrial and spacecraft life-support systems, the electrolyzers could be used to regenerate breathable O_2 from CO_2.

The proposed electrolyzers would amount in effect to molten-carbonate fuel cells optimized for operation in reverse. Solid-oxide electrolyzers (usually containing zirconia solid electrolytes) would be the closest competitors, were it not for their relative fragility, susceptibility to leakage, and necessity of very high operating temperatures. Sabatier systems would be the next closest competitors, except that hydrogen must be supplied for operation, making them impractical in the intended applications. Other would-be competitors include glow-discharge reactors, which must be powered with high voltages and currents; and reverse water-gas reactors, for which catalysts must be regenerated.

Molten-carbonate fuel cells have been investigated extensively, but not with respect to reverse operation for electrolysis. It should be a simple matter to adapt a commercial off-the-shelf molten-carbonate fuel cell for initial experiments in electrolysis. Topics that must be addressed in efforts to develop molten-carbonate electrolyzers include stability of the electrolytes and extension of operating lifetimes, which are short. The use of modern materials, including stabilizers for the electrolytes, is expected to be an important part of the proposed development efforts.

This work was done by Kumar Ramohalli and Gerald Voecks of Caltech for **NASA's Jet Propulsion Laboratory**. *For further information, access the Technical Support Package (TSP)* ***free on-line at www.nasatech.com*** *under the Physical Sciences category.*
NPO-20468

Improved Spherical Energy Analyzer

NASA's Jet Propulsion Laboratory, Pasadena, California

An improved spherical energy analyzer (a type of electrostatic mass spectrometer) is under development for use in analyzing a beam of ions generated by a Hall thruster. The major improvement, relative to a commercial spherical energy analyzer, is the addition of a quadrupole stage (with refocusing electron optics) for separating ions of different charge states. The development work also includes efforts to make the instrument smaller and lighter than the commercial version in order to make it possible to translate and rotate the instrument through the ion beam inside a vacuum chamber that contains the Hall thruster.

This work was done by Dennis Fitzgerald and James Cooley of Caltech for **NASA's Jet Propulsion Laboratory**. *For further information, access the Technical Support Package (TSP)* ***free on-line at www.nasatech.com*** *under the Physical Sciences category.*
NPO-21116

Redundant Oxygen-Deficiency Monitoring System

John F. Kennedy Space Center, Florida

An oxygen-deficiency monitoring system (ODMS) has been developed for a ten-room facility in which the use of large amounts of nitrogen and helium could cause an oxygen deficiency severe enough to be hazardous to personnel. The ODMS comprises three subsystems, of which two monitor three rooms each, and one monitors four rooms. The ODMS generates alarms when the oxygen content of the air in a room falls below 19.5 mole percent. Each subsys-

tem includes transport pumps that draw air continuously from each room through two tubes. Each subsystem includes two oxygen analyzers equipped with sampling pumps, plus two programmable-logic controllers (PLCs) and associated hardware that control electrically actuated valves that admit small fractions of the transport flows to the oxygen analyzers. The PLCs cause the valves to connect the two oxygen analyzers to two different sampling tubes, and then to switch the connections to a different pair of sampling tubes after an interval of about 10 seconds, and so forth until the air from all sampling points has been monitored, and then the sequence repeats. If one sampling tube, oxygen analyzer, pump, or PLC fails, it can be repaired while the system continues to operate, albeit at a reduced rate.

This work was done by Paul A. Mogan of **Kennedy Space Center** *and Richard J. Hritz, Donald C. Young, Wayne E. Rutherford, Guy Naylor, and Francisco Lorenzo-Luaces of Dynacs Engineering Co., Inc. For further information, access the Technical Support Package (TSP)* ***free on-line at www.nasatech.com*** *under the Physical Sciences category.*
KSC-12067

Thermal Detection of Gas in a Tube Containing Flowing Liquid

A decrease in temperature downstream of a heater would indicate intrusion of gas.

NASA's Jet Propulsion Laboratory, Pasadena, California

A relatively simple thermal technique has been proposed to enable detection of bubbles of gas or bulk gas in a tube that is meant to contain a flowing liquid only. In a system in which gas cannot be tolerated, the technique could be used to trigger a shutoff valve downstream of a location where gas is detected.

The technique would involve the placement of a circumferential electrical heating element around the tube and a circumferential thermometer around the tube a suitable short distance downstream of the heating element. The thermometer reading would be indicative of the rate of transfer of heat from the heating element to the thermometer; this rate would depend on the temperature of the heater, the rate of convective transfer of heat between the tube and the fluid at the heater and thermometer locations, and the thermal capacity of the fluid in the tube. These variables and thus the thermometer reading would be affected by any gas that might be present.

A device to implement the technique could be fabricated by placing a thin layer of a dielectric material around the tube, sputtering a thin platinum coat over the dielectric, and patterning the platinum into narrow rings around the tube at two (or more for redundancy) positions along the tube. The upstream platinum ring would be operated as a heater and resistance thermometer, and the downstream platinum ring would be operated as a resistance thermometer. For a specific combination of heater temperature and rate of flow, the temperature sensed by the downstream resistance thermometer would include a component proportional to the transport of heat by thermal mass flow in the tube. Intrusion of gas into the tube would reduce the effective thermal mass density of the fluid in the tube, and the temperature read by the downstream resistance thermometer would decrease accordingly.

This work was done by Frank T. Hartley of Caltech for **NASA's Jet Propulsion Laboratory**. *For further information, access the Technical Support Package (TSP)* ***free on-line at www.nasatech.com*** *under the Physical Sciences category.*
NPO-20996

Theory of Formation-Flying Control for Multiple Spacecraft

A report presents the mathematical basis of a method of controlling multiple spacecraft flying in formation, subject to control constraints. The spacecraft are assumed to be equipped with relative-position-sensing, relative-velocity-sensing, and communication infrastructure, and with maneuvering actuators. The method involves a leader-following control scheme. A graph is used to represent the hierarchy of, and the data dependencies among, the leading and following spacecraft. Graph-theoretic concepts are shown to play a vital role in determining the basic properties of the leader-following control architecture; hence, changes in the hierarchy (represented by changes in the graph) translate directly to the required changes in control.

This work was done by Fred Hadaegh and Mehran Mesbahi of Caltech for **NASA's Jet Propulsion Laboratory**. *To obtain a copy of the report, "Formation Flying Control of Multiple Spacecraft via Graphs, Matrix Inequalities, and Switching," access the Technical Support Package (TSP)* ***free on-line at www.nasatech.com*** *under the Mechanics category.*

NPO-20902

Self-Organization Based on Quantum Entanglement

A report presents a theoretical study of communication among intelligent agents in the presence of quantum entanglement and the absence of classical (in the sense of non-quantum) communication channels. Several paradigms of self-organization based on quantum entanglement are introduced and discussed. These paradigms include inverse diffusion, transmission of conditional information, decentralized coordination, cooperative computing, competitive games, and topological evolution in active systems.

This work was done by Michail Zak of Caltech for **NASA's Jet Propulsion Laboratory**. *To obtain a copy of the report, "Entanglement-Based Self-Organization," access the Technical Support Package (TSP)* ***free on-line at www.nasatech.com*** *under the Information Sciences category.*

NPO-30192

Onboard Estimation of Times of Periapsis During Aerobraking

A report proposes a technique for onboard updating of the orbital period of an aerobraking spacecraft in order to estimate the time of the next periapsis. The time of periapsis is nearly centered in the middle of the drag pass, and provides a convenient reference time for events in the sequence that controls the activities taking place onboard the spacecraft. Heretofore, updates of periapsis times have been computed on Earth on the basis of radio tracking data, then uplinked to the spacecraft. Onboard updating could increase operational efficiency and reduce costs by reducing the amount of ground and tracking support needed.

This work was done by Daniel T. Lyons of **NASA's Jet Propulsion Laboratory**, *Robert H. Tolson of George Washington University, and James Longuski of Purdue University. To obtain a copy of the report, "Simple Autonomous Timing Update During Aerobraking," access the Technical Support Package (TSP)* ***free on-line at www.nasatech.com*** *under the Mechanics category.*

NPO-30155

Report on User's Guide for Monthly Vector Wind Profile Model

A report briefly describes a user's guide for a computer program that constructs vector wind profiles on the basis of a statistical model. The monthly vector wind profiles are meant to be used (1) to estimate wind-dispersion-related dispersions of critical aerodynamic loads and corresponding aerospace-ascent-vehicle design parameters and (2) to analyze effects of monthly wind-profile dispersions on ascent trajectories and to design ascent autopilot systems to correct for these effects. The user's guide is

also said to list output data to aid the user in the verification of test output.

This work was done by Stanley I. Adelfang of Computer Sciences Corp. for **Marshall Space Flight Center**. *To obtain a copy of the report, "Users Guide for Monthly Vector Wind Profile Model," access the Technical Support Package (TSP)* ***free on-line at www.nasatech.com*** *under the Physical Sciences category.*
MFS-31431

Experiments on Residual-Stress Bondline Failures in an RSRM

A report describes an experimental study undertaken to verify a finite-element mathematical model used to predict residual stresses and stress-induced failures in the adhesive interfacial layers (bondlines) that join phenolic liners to interior surfaces of metal housings of reusable solid rocket motors (RSRMs). The model reflects the three-dimensional complexity of the stress fields in question and includes time- and temperature-dependent constitutive and failure properties of the adhesive material, which exhibits nonlinear viscoelasticity.

This report was done by David E. Richardson, Bradley R. Hoskins, Theodore J. Lewis, and Alan V. Palumbos of Thiokol Corp. for **Marshall Space Flight Center**. *To obtain a copy of the report, "Verification of Finite Element Predictions of Residual Stress Bondline Failures in a Full-Scale Test Article," please contact Jim Ekstrom at* james.ekstrom@Thiokol.com.
MFS-31321

Improved Micromachined Vaporizing-Liquid Microthruster

A report describes an improved micromachined vaporizing-liquid microthruster (VLM), now under development as a prototype of thrusters for microspacecraft. This thruster is of the resistojet type: the energy for vaporization and expansion of a propellant liquid is provided through electrical-resistance heating. A typical VLM of prior design, fabricated on a chip, was comparatively bulky and was energy-inefficient because much of the energy that should have gone into heating the propellant was wasted in heating the chip.

This work was done by David Bame, Indrani Chakraborty, Juergen Mueller, and Stephen Vargo of Caltech for **NASA's Jet Propulsion Laboratory**. *To obtain a copy of the report, "Micro Machined Vaporizing Liquid Microthruster (VLM) with Superior Thrust Vector Control and Increased Thermal Efficiency," access the Technical Support Package (TSP)* ***free on-line at www.nasatech.com*** *under the Machinery/Automation category.*
NPO-21100

Sizes of Surface and Capped $In_xGa_{1-x}As/GaAs$ Quantum Dots

A report describes an experimental study of the sizes and concentrations of capped (buried) and surface $In_{0.6}Ga_{0.4}As/GaAs$ quantum dots that were grown by metal-organic vapor deposition under the same conditions except for the inclusion or exclusion of capping. [$In_xGa_{1-x}As/GaAs$ quantum dots are lens-shaped islands (typically a few nanometers thick and tens of nanometers in diameter) of $In_xGa_{1-x}As$ grown on a GaAs substrate. As used here, "capping" signifies the growth of a layer of GaAs over the $In_xGa_{1-x}As$ islands.] In the experiments, the sizes of the capped $In_{0.6}Ga_{0.4}As/GaAs$ islands were measured by transmission electron microscopy (TEM).

This work was done by Rosa Leon of Caltech for **NASA's Jet Propulsion Laboratory**. *To obtain a copy of the report, "Adatom condensation and Quantum Dot sizes in InGaAs/GaAs (001)," access the Technical Support Package (TSP)* ***free on-line at www.nasatech.com*** *under the Physical Sciences category.*
NPO-21010

Fuel Cell Would Generate Power From Martian Atmosphere

A report proposes the development of a thin-film fuel cell that would generate electric power from two minor constituents of the Martian atmosphere — O_2 and CO. These compounds are generated continuously by photolysis of CO_2, the major constituent. The fuel cell would include a cathode and an anode made of catalysts suitable for the selective low-temperature electrochemical reduction of O_2 and oxidation of CO, respectively. It would also include a hygroscopic gel electrolyte.

This work was done by Joseph Lewis and Christopher England of Caltech for **NASA's Jet Propulsion Laboratory**. *To obtain a copy of the report, "Indigenous Martian Atmospheric Power (IMAP)," access the Technical Support Package (TSP)* ***free on-line at www.nasatech.com*** *under the Physical Sciences category.*
NPO-30123

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Product Development

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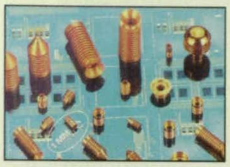
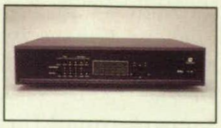
Miniature Bellows Contacts



Servometer®, Cedar Grove, NJ, offers miniature bellows contacts for applications where contact with a delicate component or material is required. The contacts are rated for a maximum current of 4 amps. They minimize shock and vibration, and help to overcome tolerance buildup and misalignment problems. Servometer® contacts have low insertion forces, low insertion losses, and low DC resistance. **For Free Info Circle No. 720 or Enter No. 720 at www.nasatech.com/rs**

Digital Recording System

The DGx™ digital recording system from RGB Spectrum, Alameda, CA, captures, compresses, and stores images up to 1280 x 1024 pixels. Computer, radar, video and audio acquisition, time-code, and event markers are supported. The unit accepts up to four image sources for recording to digital tape or disk. It digitizes inputs in real time and plays back from 6 to 25 frames per second, depending on image resolution. It can handle up to four images simultaneously which, on playback, can be displayed on one or two monitors. **For Free Info Circle No. 721 or Enter No. 721 at www.nasatech.com/rs**



Visualization System

The RenderDrive™ RD5000 rendering system from Advance Rendering Technology, Mountain View, CA, uses physically accurate rendering methods to produce lifelike lighting, textures, and reflections on a variety of materials. It uses a silicon solution based on ray tracing to deliver 3D rendering. The system is platform and application independent, and can be used with Windows and UNIX platforms as well as 3D applications such as Solid Edge, SolidWorks, and Pro/ENGINEER. **For Free Info Circle No. 722 or Enter No. 722 at www.nasatech.com/rs**

Data Visualization Software

Visual Numerics, Boulder, CO, has released PV-WAVE Version 7.5 software that allows engineers, researchers, and scientists to understand datasets using a variety of visual techniques. The software's interactive, array-based scripting language lets users develop platform-neutral applications for manipulating, analyzing, and visualizing datasets to detect and display trends, patterns, and anomalies. The software includes mathematical and statistical functions, image processing, signal processing, and general mapping functionality. **For Free Info Circle No. 723 or Enter No. 723 at www.nasatech.com/rs**

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New LITERATURE

Rugged Portable Workstation

A four-page brochure from FieldWorks, Eden Prairie, MN, details the features of its FW8000 Series Field WorkStation rugged portable computer that includes a Pentium® II processor, weather-resistant keyboard, and a choice of XGA or SVGA displays. The unit contains an internal and removable hard drive and sunlight-readable display. It provides connection for up to three full-length or six half-length ISA or PCI expansion cards. **For Free Info Circle No. 711 or Enter No. 711 at www.nasatech.com/rs**

Polyurethane Foams

Crest Foam Industries, Moonachie, NJ, offers literature describing its FeltCrest™ compressed polyurethane foams for applications such as metering, wicking, gasketing, backing, cushioning, and sound absorption. The materials are available in a variety of compression ratios from 3 to 1 to 10 to 1. **For Free Info Circle No. 712 or Enter No. 712 at www.nasatech.com/rs**

Sensing Systems

Oceana Sensor Technologies, Virginia Beach, VA, has released literature detailing sensing systems for applications such as machinery health monitoring. Intelligent component health monitors (ICHM™) provide information about pressure, oil condition, motor current, acoustic emission, vibration, temperature, and other operational functions. Other sensors are embedded in machinery to detect symptoms of deterioration and then transmit findings across a wired or wireless network to a system health monitor. **For Free Info Circle No. 713 or Enter No. 713 at www.nasatech.com/rs**

Sockets and Interconnects

A brochure from Andon Electronics Corp., Lincoln, RI, highlights IC sockets, adapters, interconnects, and contact/terminal products. Featured are BGA Rollerball™ Sockets for PCB coplanarity assembly. Also featured are test solutions and probes, and jumpers, pin headers, and receptacles. **For Free Info Circle No. 714 or Enter No. 714 at www.nasatech.com/rs**

Data Acquisition/Instruments

A CD Databook from Newport Electronics, Santa Ana, CA, provides thousands of pages of reference material, specifications, and manuals for the i™ Series panel maters, controllers, and signal conditioners with an embedded Web server. The Databook includes free software for data acquisition and configuring of Newport instruments, free ActiveX controls, and a free OPC server. **For Free Info Circle No. 715 or Enter No. 715 at www.nasatech.com/rs**

DATA ACQUISITION AND INSTRUMENTATION eCATALOG

This free 37-page short-form catalog from IOtech features product overview charts and selection guides for IOtech's wide range of data acquisition systems and signal conditioning options. New products include the ScanWare™ family of products for Ethernet-based data acquisition and a new multi-function, 8-channel counter/encoder module for the portable data acquisition systems. IOtech, Inc.; Tel: 440-439-4091; Fax: 440-439-4093; email: sales@iotech.com; website: www.iotech.com

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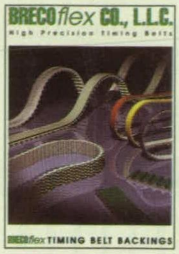

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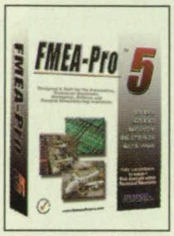

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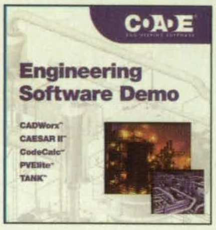

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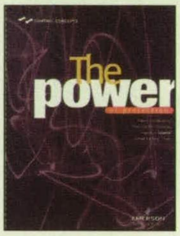

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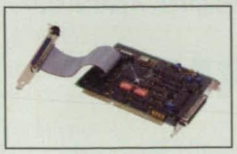
LOW-COST 12-BIT DATA ACQUISITION SYSTEM



OMEGA's DAQ-801/802 is a low-cost data acquisition system with 12-bit resolution, eight-channel analog input, two-channel D/A output, 32-bit digital I/O, and one 16-bit programmable timer/counter for ISA bus computers (IBM PC/AT or compatible). The maximum sampling rate is 40 KHz for A/D with internal or external triggering. The DAQ-801/802 offers software-selectable, eight-channel, single-ended or differential analog inputs with 12-bit resolution. OMEGA Engineering, One Omega Dr., Stamford, CT 06907; Tel: 1-888-TC-OMEGA; www.omega.com

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INSTRUNET SERIES DIRECT SENSOR TO DATA ACQUISITION

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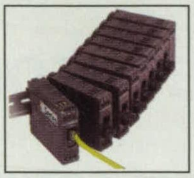

Connect Your DRX Modules through an Ethernet Connection. The EIS Embedded Internet module is a standalone device that will allow you to connect to your DRX modules through an Ethernet connection. The EIS module is a DIN rail device that can be a hub connecting up to 32 instruments to the Ethernet and Internet. The EIS module is both a Web Server and an Ethernet-Serial bridge. OMEGA Engineering, One Omega Dr., Stamford, CT 06907; Tel: 1-888-TC-OMEGA; www.omega.com

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RUGGED, PORTABLE DATALOGGING SYSTEMS

OM-3000 Series dataloggers take making measurements and downloading them to your PC for further analysis or archiving extremely easy. Input ranges, user-defined session names and sampling intervals are easily programmed via the built-in keypad. With the standard 128K memory, approximately 100,000 individual samples with date/time stamp can be stored in the datalogger for downloading. OMEGA Engineering, One Omega Dr., Stamford, CT 06907; Tel: 1-888-TC-OMEGA; www.omega.com

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PORTABLE, LOW-COST DATALOGGERS

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4-CHANNEL TEMPERATURE DATALOGGER

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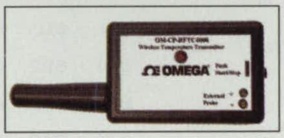
WIRELESS THERMOCOUPLE TEMPERATURE TRANSMITTER



The OM-CP-RFTC4000 is a miniature, wireless, battery powered, standalone, thermocouple-based temperature transmitter. This all-in-one, compact, portable, easy to use device will measure and transmit temperature measurements. It can be started and stopped instantly through an externally accessible pushbutton. OMEGA Engineering, One Omega Dr., Stamford, CT 06907; Tel: 1-888-TC-OMEGA; www.omega.com

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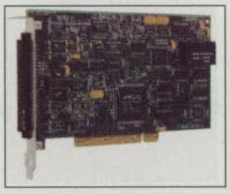
PCI BUS 16-CHANNEL ANALOG INPUT BOARD



The PCI-DAS 1001 and PCI-DAS 1002 multifunction analog and digital I/O boards set a new standard for low-cost, medium-speed data acquisition on the PCI bus for IBM or compatible PCs. It offers 16 single-ended or 8 differential 12-bit analog inputs with sample rates up to 150 KHz, 24 bits of digital I/O and three 16-bit counters. In addition, the PCI-DAS 1000 series offers two 12-bit analog outputs. OMEGA Engineering, One Omega Dr., Stamford, CT 06907; Tel: 1-888-TC-OMEGA; www.omega.com

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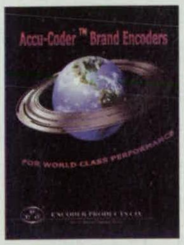

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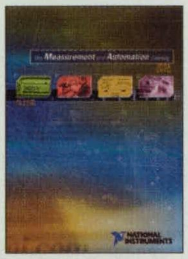

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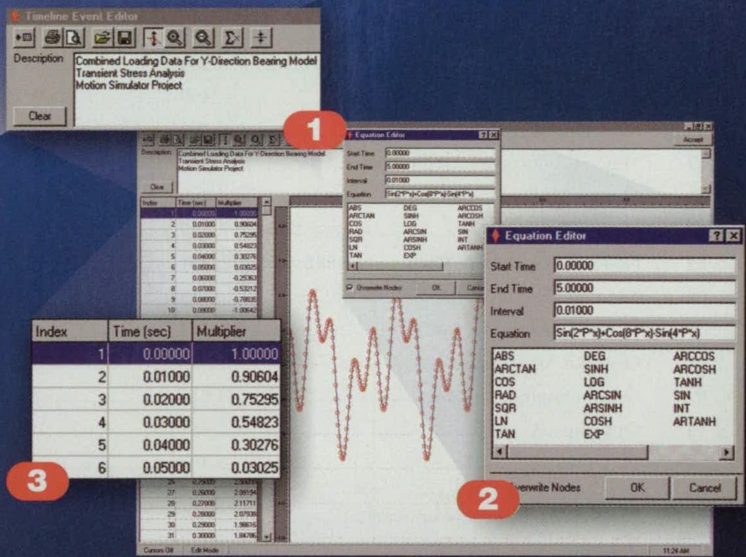
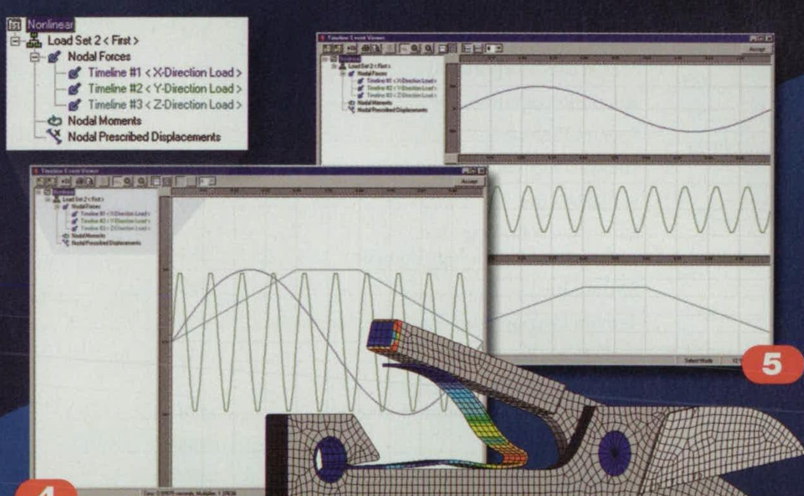
761	762	763	764	765	766	767	768	769	770
771	772	773	774	775	776	777	778	779	780
781	782	783	784	785	786	787	788	789	790
791	792	793	794	795	796	797	798	799	800
801	802	803	804	805	806	807	808	809	810
811	812	813	814	815	816	817	818	819	820
821	822	823	824	825	826	827	828	829	830
831	832	833	834	835	836	837	838	839	840

SIMULATING REAL-WORLD EVENTS JUST GOT EASIER WITH

TIMELINE



Timeline's Event Editor provides click-and-drag points for easy curve definition as well as: 1 export functionality and a library manager; 2 Equation Editor for curve creation from designated inputs and 3 tabular entry for curve data.



The Event Viewer can plot multiple curves 4 together or 5 separately to show how multiple physical phenomena will simultaneously act on a model during analysis.

ALGOR's Timeline Event Manager graphical utility enables engineers to quickly and easily define and visualize time-based event curves for Mechanical Event Simulation, transient structural analysis and transient thermal analysis. It simplifies the setup of complex real-world events by simultaneously plotting curves for multiple analysis types to show exactly how variables will interact.

TIMELINE EVENT MANAGER FOR:

- **Mechanical Event Simulation (MES)**
- **Transient Structural Analysis with Linear and Nonlinear Material Models**
- **Transient Thermal Analysis**

- Graphical visualization of curve data helps engineers catch input errors during analysis setup.
- A built-in Equation Editor uses start times, end times and a library of supported functions to generate event curves.
- Built-in spreadsheet provides fast entry or modification of magnitude versus time data.
- Multiple load curves can be depicted on a single plot in the Event Viewer for multiphysics analyses.
- Points on any plot can be dynamically dragged to new locations.
- Timeline integrates with Microsoft applications including Excel.
- A library stores frequently referenced, user-defined curves.
- Timeline works within CAD for a value-added modeling solution.

Watch a free Internet Webcast at

eventmgr.ALGOR.com

to learn about the Timeline Event Manager for performing time-dependent and multiphysics analyses with ALGOR software.

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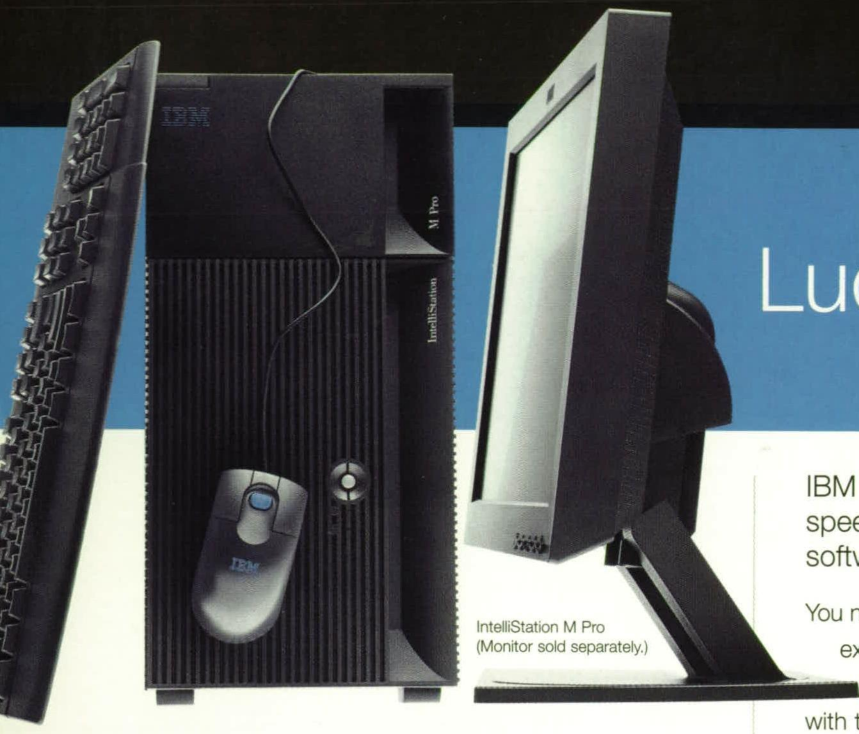

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